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LINOSA AND ITS ROCKS

HENRY S. WASHINGTON

INTRODUCTION

In the present paper are described the geology and petrology of a small islet in the Mediterranean which, up to the present, has remained almost unknown to geologists. The observations and collections on which the paper is based were made in September, 1905, in the course of a trip to some of the less-known volcanoes of the western Mediterranean, undertaken for the Carnegie Institution of Washington, to the trustees of which I am indebted for permission to publish this paper here.

About half-way between Malta and the coast of Tunis three small islets—Linosa, Lampedusa, and Lampione—project above the sea, which are called collectively the Pelagic Islands (Isole Pelagie). While geographically grouped together, geologically they are very diverse, Linosa being entirely volcanic, while Lampedusa and Lampione are composed wholly of limestone.

Although this paper deals properly with Linosa alone, it may yet be of interest to record a few facts about Lampedusa.[1] This island, the largest of the group, is of narrow, oblong shape, the greatest length (east and west) being eleven kilometers, and the greatest breadth (north and south) about three kilometers, almost at the eastern end. It is essentially a tilted block of limestone, the highest

[1] Cf. W. Deecke, *Italien*, Berlin, 1899 (?), p. 479; and *Italy*, London and New York, 1904, p. 449.

point being at the west (133^{m}), and thence gradually sloping to the east end, where the general elevation above sea-level is but 20^{m}. The surface, which is in general fairly flat, is somewhat cut up by shallow erosion valleys, and there are no very prominent hills. The soil almost all over the island is stony and barren, a few gardens and vineyards being maintained with difficulty here and there, and the only trees are half a dozen date palms which are found in sheltered hollows. The rock composing Lampedusa is a white to creamy-yellow, soft limestone,[1] which is distinctly magnesian, as shown by the analysis of Speciale,[2] who has described the island briefly. According to him it is more recent than the Tertiary limestones of Malta, containing fossils of living mollusks. Lampedusa is of considerable commercial importance as the center of extensive sponge and sardine fisheries, and is the point of exchange for the sponge trade of the Mediterranean, the sponges from the Greek islands being largely brought here.[3]

Lampione, which lies about 8 nautical miles west of Lampedusa, is a mere rock, barely 400 meters across, 43 meters high at its western end, and sloping to sea-level at the east. It is said to be composed of limestone similar to that which forms Lampedusa.

GEOLOGY OF LINOSA

Bibliography.—The literature on the geology of Linosa is very scanty, commensurate with its small size and isolation, and its political and commercial insignificance. For the most part the papers which deal with it belong to the first half of the nineteenth century and are of little modern value. A list of them is given by Speciale. The standard general works on volcanoes either ignore or barely mention the island, Scrope,[4] for instance, giving it but three lines of description.

Mercalli,[5] who bases his account on the work of Calcara[6] (an author

[1] Lampedusa and Lampione are incorrectly colored as volcanic on Sheet 45 of the Carte géologique internationale de l'Europe. I saw no igneous rock on the island.

[2] S. Speciale, *Boll. Com. Geol. Ital.*, Vol. XV, 1884, p. 263.

[3] My thanks are due Signor S. di Maggio for courtesies and assistance during my few hours on Lampedusa.

[4] G. P. Scrope, *Volcanoes*, London, 2d ed., 1862, p. 345.

[5] G. Mercalli, *Vulcani d'Italia*, Milano, 1883, p. 161.

[6] P. Calcara, *Descrizione dell' isola Linosa*, Palermo, 1851, pp. 30.

whom I have been unable to consult), gives a page of description, with considerable detail as to altitudes, etc. He makes mention of but four volcanoes, but it is interesting to note that Calcara recognized the two periods of vulcanicity to be described later, though his "trachytic" rocks are shown by my observations and analyses to be basaltic tuffs, and were evidently referred to the trachytes because of their light color.

The most recent, and the only modern, paper dealing with the geology is that of Speciale,[1] which is but a preliminary one, the second part, which was to describe the petrography of the rocks, never having appeared. In this two-page paper Speciale briefly describes the general geology and several of the volcanoes, distinguishing between those of tuff and of lava, the limits of which are given on his map.

The last paper to be mentioned is that of D'Avezac,[2] who gives a general description, apparently based largely on the observations of Captain Smyth prior to 1823. The geology is summarily treated, but the history of the islet is discussed more fully, D'Avezac showing that Linosa is the *Ἀνεμοῦσα* of Ptolemy.

Three maps of Linosa are available. The most satisfactory is that found on Sheet 211 of the charts of the Italian Instituto Idrografico, on a scale of 1 : 25,000, and which has been used as the base of that which accompanies this paper. A second is found on the Linosa and Lampedusa sheet (No. 193) of the British Admiralty, on a scale of 1 : 25,100, and this sheet is of special interest because it shows a view of the island from the southwest. The third is on Foglio 265 of the topographic maps of the Instituto Geografico Militare, the scale being 1 : 50,000. In all three the various volcanoes are shown and many altitudes noted, though, between the various maps, there are discrepancies as regards these and the names.

General description.—The island of Linosa[3] lies 20 miles northeast of Lampedusa and about 59 southeast of Pantelleria. In form it is nearly a square, the sides facing the cardinal points, with a length east and west of about 3 kilometers and a breadth north and south of

[1] *Op. cit.*, p. 165, with map.

[2] D'Avezac, *Iles de l'Afrique*, Paris, 1885, p. 119.

[3] According to the British chart the lighthouse is situated in Lat. 35° 52′ N. and Long. 12° 53′ E.

2.5 kilometers, the greatest length diagonally from northwest to southeast being 3.5 kilometers. Its total area is about 6.5 square kilometers. On the map of the island as given in Fig. 1, the contour lines are only approximate and give merely a rough idea of the topography.

FIG. 1.—Island of Linosa.

Linosa is dry in the extreme, not a single spring being found on the island, and the water supply being dependent on the rains, which are collected from the flat roofs and preserved in cisterns. At the time of my visit the island was favored with the first rain in five months, and the inhabitants were reduced to a daily ration of two liters of water apiece, a supply having had to be brought by a government vessel from Sicily. The greater part of the surface, where it is not bare lava and tuff, is covered with sterile sand and ashes, and in the few cultivatable areas, which are fenced in with opuntia cactus

(the fruit of which serves as food for man and the fleshy stems for beast), some sparse crops of grain are raised, or they are given over to straggling vineyards, from which a harsh, but not unpleasant, red wine is produced. Fishing is the only industry, and this barely suffices for local needs.

Communication with civilization is kept up by a small steamer, which touches at the island on its biweekly trip from Pantelleria to Girgenti, and again a day and a half later on the return voyage, touching at Lampedusa both ways. This interval was necessarily the limit of my visit, but the small size of the island enabled me to make a fairly complete study of its geology.

The earliest evidences of human occupation are seen in some ruins, which consist of long and narrow foundation walls, apparently of houses, built of blocks of tuff, and also several pot-shaped graves, lined with cement, which I saw near the summit of Monte Levante, and in which my guide said skeletons had been found. These, as well as vases and coins said to have been found on the island (none of which I saw), point to the habitation of the island in (probably) Roman times. But it was apparently abandoned during the Middle Ages and later, and remained uninhabited until 1845,[1] when some colonists were imported by the government. These earlier colonists inhabited several rude chambers hewn in the tuff on the west slope of Monte Bandiera, which are now unoccupied.[2] The modern village consists of a single street, with low, one-storied houses, and few houses are scattered about the island. At the time of my visit there were said to be about 240 persons residing on the island, including a customs officer, Signor N. Raneri, to whom I am deeply indebted for most courteous hospitality and assistance, a priest, and a government physician. A lighthouse occupies the northeast corner.

General geology.—The only rocks visible on the island are volcanic, and the whole mass has been built up out of the sea by a succession

[1] Cf. Mercalli, *op. cit.*, p. 161, note. According to D'Avezac, Captain Smyth (before 1823) found no inhabitants nor, indeed, any animal life, except some falcons. He set free on the island some goats and rabbits, and planted peas, beans, wheat, barley, tobacco, and castor beans in various places, all traces of which benefactions having now disappeared.

[2] According to Deecke (*loc. cit.*) they were abandoned in 1878.

of eruptions which formed a number of cones. The only clue to what lies beneath these is given by a small fragment of a light-colored, medium-grained, olivine-bearing, hornblende-diorite, which I found imbedded in a piece of scoria at Monte Rosso, and which is evidently a fragment of a plutonic rock from the basement brought up by the lava stream. In this respect Linosa resembles Pantelleria, where Foerstner[1] reports fragments of hornblende-granite likewise imbedded in the lava and tuffs, and which he refers to the basement complex of the island.

Small as is the island it yet shows nine distinct volcanic cones,[2] or centers of eruption, which may be referred to two distinct periods of activity, distinguished by the materials which compose them.

The first period is characterized by cones of basaltic tuff, lava being represented in these only as included blocks. Not only do these tuff cones show signs of greater age than the cinder cones in the greater extent to which they have suffered by erosion, but in many cases the tuffs are seen to be overlaid by the cinders and lavas of the cones of the second period.

In the center of the island is a rather prominent ridge of dark, greenish-gray tuff, running north and south, to which the name of Monte Bandiera is applied, and in the west slope of which the rude chambers mentioned above have been hewn. This ridge is the west wall of what is apparently the oldest cone of Linosa, to the east of it two distinct craters being visible. The most northerly of these, for which I could learn no name, but which may be called the North Bandiera Crater, is composed largely of yellow, with some dark-gray tuffs, which contain angular blocks of compact basalt. This crater, which measures some 300 meters across, is not very well preserved, but shows a well-defined rim on the west and south, the

[1] H. Foerstner, *Boll. Com. Geol. Ital.*, 1881, p. 550.

[2] Speciale considers that there are but five eruptive centers, namely: Monte Ponente proper (with which he includes Monte Pozzolana), the cone which I have named Monte Raneri, Monte Vulcano, Monte Rosso (of which he mentions only the barranca on the north, not speaking of the summit crater), and Monte Bandiera (which includes the two large craters immediately to the east, as well as Monte Biancarella to the north). He considers Monte Calcarella as forming a part of Monte Vulcano and does not mention the well-defined cone of Monte Levante, nor does he consider that the tuff and lava cones belong to two distinct periods.

western rim being about 150 meters above the sandy and lava-covered plain to the west and about 20 meters above the crater floor. To the east its tuffs are lost beneath the lavas and cinders of Monte Rosso. This northerly crater is older than its companion, as the tuffs of the latter cover part of its southern side, and it may be considered the oldest on the island, in view of its poor preservation and central position.

The southern crater, which is called Il Fosso, presents a flat, elliptical floor, of about the same size as that of the preceding, which is planted in vines and cactus. This crater is bounded on the north, west, and south by a well-defined rim of yellow and greenish-gray tuffs, which also contain blocks of compact basalt. This ridge reaches a height on the west, Monte Bandiera, of 102 meters, and on the south of 148 meters, this southern rim being known as Monte Calcarella. The south slopes of Calcarella are partly covered by the scoriae of Monte Vulcano, and to the east the low, ill-defined rim of Il Fosso is almost wholly buried beneath the lavas and ashes of this same volcano. A gap in the ridge on the southwest, between Monti Bandiera and Calcarella, gives access to the crater floor.

At the southeast corner of the island is a third tuff cone, that of Monte Levante.[1] Of this only the northern half remains, the southern portion having been washed away by the waves, forming a precipitous cliff and exposing a fine section, in an inaccessible outlying pinnacle of which was seen a dike of black basalt. What remains of the cone consists of thin-bedded yellow and dark, greenish-gray tuffs, which contain numerous, rather large, angular blocks of compact basalt. On the flat summit of the ridge, which is 92 meters above sea-level, weathering has developed in the tuff about these blocks a series of concentric thin shells, which resemble a nest of hemispherical basins in which the blocks lie. None of these shells were seen covering the blocks, that is, with the convexity uppermost. The origin of this peculiar structure is uncertain and, while it seems to be made evident by weathering, yet its cause must apparently be attributed to some other agency, possibly to the vibrations set up in

[1] This is the name as given on the Italian military map, and the one by which it may best be called here, though my guide called it Monte Calcarella. But this last name is given on all the maps to the southern rim of the crater just described.

the tuff by the impact of the falling block. The northern slopes of Monte Levante are covered by the scoriae of Monte Vulcano, which adjoins it on the northwest.

Monte Biancarella, which lies close to the north coast and immediately west of Monte Rosso, is a low, regular dome of yellow tuff, its summit about 50 meters above the base, and the whole about 150 meters across. There is no sign of a crater and the thin bedded tuffs dip quaquaversally on all sides, forming concentric, curving sheets, with step-like interruptions here and there due to erosion. The appearance is as if horizontal beds of tuff had been gently forced up by some invisible protrusion from below. Close to the south of this are some of the long foundation walls, constructed of blocks of tuff, which probably date from Roman times. They barely project above the surface. Excavation would be needed to expose them fully and would probably be repaid by some archaeological discoveries of interest, for which, unfortunately, time was lacking.

The last tuff cone to be described is marked Monte Ponente on all the maps, but seems to be called Monte Pozzolana by the inhabitants. As it is a composite cone, being composed both of tuff and lava, we may conveniently reserve the name Monte Pozzolana for the southern, tuffaceous portion, and let Monte Ponente denote specifically the northern, basaltic portion, though there is no orographic distinction between them. This cone is situated on the west coast of Linosa, the sea having cut away its west side and exposed a fine section. Immediately at its foot is the best landing-place of the island, a small cove, with rocky shores and a small artificial jetty, at which only small row boats can land, the steamer stopping about a mile from shore. If the wind is from the north or west, landing must be effected at the Scala Vecchia, a small bay on the south coast, likewise very rocky, and about one-third of a kilometer south of the village.

Monte Pozzolana consists of thin-bedded, very friable, yellow tuffs, which contain numerous very small fragments of somewhat scoriaceous basalt, but few large blocks, such as were noted at the other tuff cones. Toward the top the tuff mingles with, and is finally covered by, the scoriae of Monte Ponente. In the breach on the

west side is a vertical dike about 70 centimeters wide, of finely vesicular black basalt, which cuts through the yellow tuff beds, but not through the black scoriae above. The sides of this dike show distinct marks of flow, and it has not altered appreciably the yellow tuffs.

Of the cinder and lava cones, which mark the second period of vulcanicity, the highest is Monte Vulcano, immediately southeast of Monte Calcarella, and on the south coast of the island. The summit of this I measured with an aneroid as 199 meters above sea-level, while the Italian military map gives it as 195 meters, and the Italian hydrographic map as 160.[1] About 14 meters below the summit of this volcano is a well-preserved, circular crater, about 100 meters in diameter and 30 meters deep, the steep walls composed of scoria and blocks of lava. On the south slope of the volcano, toward Monte Levante, are many vesicular lava flows, interbedded with tuffs, and lava flows and cinder slopes are also seen on the east side. On the west side, some 80 meters below the summit, is an almost horizontal plateau, the upper surface of a series of six or eight lava flows, each a meter or so thick, frequently with a rough columnar structure, and separated from each other by thin layers of scoriaceous material. On the upper edge of this plateau is a natural pit, with an orifice about two by three meters across, and about fifteen meters deep, so far as one can see, from which issues constantly a strong stream of cold air, resembling a somewhat similar orifice at the Kaimeni, on Methana, in Greece, and the *bufadores* of Catalonia. On the south slope, below this plateau, are some bedded tuffs and a steep *sciarra* of lapilli which extends down to the water's edge and which closely resembles that of Stromboli. Elsewhere the sides of the cone are covered with scoriae and blocks of lava, with small lava flows here and there. As was noted above, the products of this volcano cover the lower slopes of Monte Calcarella on the northwest and of Monte Levante on the southeast, thus showing its later date.

The next highest cone of Linosa is Monte Rosso, in the northeast corner of the island. According to my aneroid this is 196 meters high, while the Italian maps give it as 186 meters, and the English one as 610 feet (186^{m}), so that it is only a trifle lower than Monte

[1] The British Admiralty chart gives the height as 525 feet (129^{m}), which is certainly much too low, and is possibly an error for 625 feet (191^{m}).

Vulcano. This is a typical, breached cinder cone, the outer slopes well preserved on the east, south, and west, but opened up on the north flank by a long, narrow, and deep *barranca*, which leads up nearly to the top, the upper part being edged by a narrow *arête* of rough lava on either side. Near the summit is a well-defined, almost circular crater, some 75 meters across, and whose floor is 20 meters below the highest point of the rim on the north, between it and the head of the barranca. Monte Rosso is composed almost wholly of rough scoriae and lapilli, to whose general red color the name of the cone is due, though some blocks of compact lava are seen here and there, and flows from near the base and from the mouth of the barranca have covered the island to the northeast, north, and northwest. Possibly some of the lavas to the south also belong to this cone, but the line of demarkation between these and the lavas of Monte Vulcano laid down on Speciale's map could not be made out by me, the surface being covered largely with sand and soil and partly given over to cultivation.

Immediately to the west of the mouth of the northerly barranca, and east of Monte Biancarella, is a small parasitic cone of reddish scoria, in which were found crystal fragments of feldspar and of a black hornblende, which is peculiar in containing 8.47 per cent. of TiO_2, and which will be described elsewhere. The occurrence of hornblende here is mentioned by Speciale. Similar crystals are said to be found at one other spot, on the east coast near I Faraglioni, south of the lighthouse, but I did not visit this locality.

The third cinder cone is that of Monte Ponente, on the west coast, which, as we have seen, is in close conjunction with the tuff cone of Monte Pozzolana, joining this on the north. At the summit, which my aneroid made out to be 98 meters above sea-level, (the Italian military map giving 107, and the Italian hydrographic map 92), is a small circular crater, with a diameter at the bottom of about 33 meters and a depth of 25 meters. The walls are precipitous and are composed of scoriae and lava blocks.

This volcano has poured out several large flows to the north and northeast, the place where the uppermost one of these has broken through the underlying yellow tuff of Monte Pozzolana being well seen in part of the section exposed by sea action on the northwest.

About half-way up a massive stream of black basalt, several meters thick, pierces the tuff, which it has reddened for some distance around. On the west coast, south of Ballata Piatta Point (the northwest corner of the island), six superposed flows are visible, which vary in thickness from one-half to one meter, and are separated from each other by scoriaceous bands. These flows of Monte Ponente, the surface of which is very rough and wholly devoid of cultivation, cover the surface to the northwest, north, and northeast of the cone, and extend into the sea, forming a very jagged shore line. On this lava surface, to the northeast of Monte Ponente and to the northwest of Monte Bandiera, are large knolls and hummocks of rough, large lava blocks, rudely piled on one another. These are apparently the remains of fallen-in lava caverns, or are possibly due to local explosions of steam.

From the relations of the two it is clear that the lavas and scoriae of Monte Ponente were ejected from the north flank of the already formed tuff cone of Monte Pozzolana, and that the two are geographically but a single mass, though petrographically quite distinct. So far as can be seen, however, there was only a little shifting of the vent northward when the second period was initiated.

To the east of Monte Ponente is an unnamed cone, for which I propose the name of Monte Raneri, after that of my host. This is 73 meters high, and shows a well-defined elliptical crater at the summit. The greater part of this cone is scoriaceous, but some lava flows are visible, and there are many blocks of a compact basalt, which differs from the others on the island in the greater abundance and size of the olivine phenocrysts. Monte Raneri is evidently older than Monte Ponente, as the scoriae of this latter cover the northwest flanks of the former.

From the characters and relations of the tuff and of the lava and cinder cones, it is quite clear that the former belong to an earlier and distinct period of activity. The tuff cones are all lower than those of the other kind, and their forms have suffered much more from erosion and their craters are not as well preserved, though this is probably due in part to the difference in the materials. Furthermore, as we have seen, when the two occur together the tuffs underlie the scoriae and lavas. Also, at Monte Pozzolana and Monte Levante

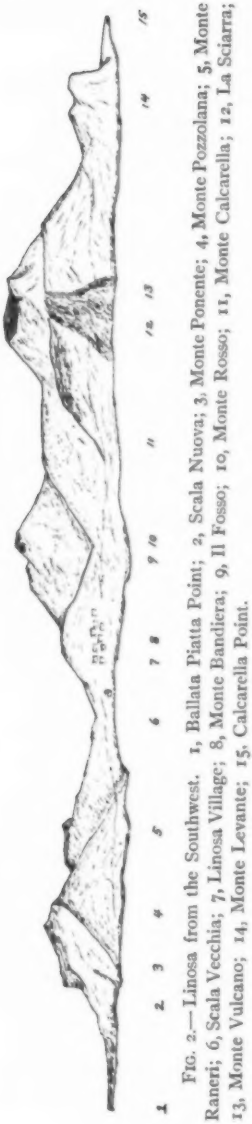

FIG. 2.—Linosa from the Southwest. 1, Ballata Piatta Point; 2, Scala Nuova; 3, Monte Ponente; 4, Monte Pozzolana; 5, Monte Raneri; 6, Scala Vecchia; 7, Linosa Village; 8, Monte Bandiera; 9, Il Fosso; 10, Monte Rosso; 11, Monte Calcarella; 12, La Sciarra; 13, Monte Vulcano; 14, Monte Levante; 15, Calcarella Point.

dikes and flows of basalt penetrate the tuffs. But it seems to be equally clear that, while the period of formation of the tuff cones antedated that of the lava ones, yet that in some cases, at least, the closing phases of the tuff cones coincided with the activity of the lava and cinder ones, as is shown by the intercalation of tuffs and lavas on the southeast slope of Monte Vulcano, and the intermingling of the tuffs of Monte Pozzolana and the scoriae of Monte Ponente in the upper portions of the mass. The usual presence of blocks of lava, scattered through the tuffs, points to the existence of lava flows beneath the surface at the time of the tuff eruptions, fragments of which were hurled up with the looser material. It might seem that the blocks in the tuff of Monte Levante have been ejected from the neighboring Monte Vulcano, as they are especially prominent in the upper beds. But this supposition is negatived by the fact that, while chemically similar to the later lavas of Vulcano, they belong to a different petrographic type, similar to that of the blocks in the other tuffs, and quite distinct from the usual types of the later lavas, as will be brought out later.

As to the geological age of these eruptions, the total absence of sedimentary and fossiliferous rocks precludes any definite evidence. But the well-preserved state of the cinder cones, the sharpness of outline of their craters and of the barranca at Monte Rosso, and the gen-

eral freshness of their lavas and scoriae, point unmistakably to their eruption in recent times. The lack of almost any reference to the island by ancient writers leaves us without any documentary data, but the presence of the graves in the tuffs of Monte Levante and of ruins near Monte Biancarella and in the north crater of Monte Bandiera proves that the extinction of these tuff cones, at least, antedates human occupation. No hot springs nor other evidences of present vulcanicity are found on the island, and its volcanoes must be regarded as extinct.

To recapitulate the apparent facts as to the order of eruption of the several cones, my observations show that the tuff cones belong to an earlier period than those of lava, though it is probable that the two periods overlapped to a slight extent. Of the former the north crater of Monte Bandiera is almost certainly the oldest on the island, followed, probably soon after, by the south crater, the so-called Il Fosso. Monti Levante, Pozzolana, and Biancarella are, almost unquestionably, later than these, and it seems probable that the date of the two former is prior to that of the last named, though the exact order is impossible to ascertain. It is more difficult to determine the sequence of the lava and cinder cones, as the relations of their several flows when adjoining, are, except in one instance, obscured by superficial sands, ashes, and cultivated soil. From their size it would seem reasonable to ascribe the eruptions of Monti Rosso and Vulcano to a rather early period, while Monte Raneri is probably of a later date, and is certainly earlier than Monte Ponente, the eruption of which may be regarded as closing the era of volcanic activity.

From the submarine topography indicated on the map (Fig. 1), it is probable that submarine eruptions, similar to those of the islands of 1831 and 1891 near Pantelleria, have taken place to the north and to the southeast of Linosa. It may be noted that rock is indicated on the chart as forming the sea-bottom at both these points, surrounded by sands.

In Fig. 2 is shown a view of the island from the southwest, based on a sketch made by me when leaving the island, as, unfortunately I had no camera with me during my visit. While somewhat diagrammatic, it yet shows the relative positions, shapes, and sizes of

the various cones, each of which may be easily identified, as well as the general appearance of the island.

PETROGRAPHY OF LINOSA

The lavas of Linosa are all feldspar-basalts according to the prevailing rock classifications, though a few contain very small amounts of nephelite, but scarcely sufficient to entitle them to the name of nephelite-basalt if account be taken of the quantitative relations. According to the quantitative system of classification recently proposed,[1] they are similarly monotonous, all of those analyzed and presumably all the others collected, so far as can be judged from the microscopic examination, falling in the subrangs camptonose (III. 5. 3. 4) and auvergnose (III. 5. 4. 4–5). Mineralogically they are very uniform and simple, the only constituent minerals being plagioclase, augite, olivine, and titaniferous magnetite, with occasionally some glass and traces of nephelite in a few instances. In the basalts themselves neither hornblende nor biotite could be detected, though crystals of hornblende occur loose in scoria at one or two points, as was noted above. The tuffs have apparently been derived from basaltic magmas, and will be briefly described after the basalts.

While the basalts vary from quite compact to highly vesicular and scoriaceous forms, such differences may be disregarded as being purely adventitious. They are all porphyritic, phenocrysts of olivine and of augite being present in every case, accompanied by abundant ones of feldspar in many of the flows, while in others feldspar phenocrysts are rare. But in the great majority of cases these megascopic differences largely disappear in the thin section, and even megascopically the extremes grade into one another to such an extent, and are connected by so many transition forms, that, as regards the majority of the rocks, a well-marked separation of the two is impossible, while the extremes may be referred to two distinct types, chiefly characterized by the abundant presence or almost complete absence of feldspar phenocrysts, as well as by certain slight chemical differences. A third type is more distinct, but even this would probably be found to intergrade with the others, were more specimens available.

[1] Cross, Iddings, Pirsson, and Washington, *Quantitative Classification of Igneous Rocks*, Chicago, 1903.

As has been explained elsewhere,[1] in connection with the Catalan basalts, since the modes and textures of these basalts are usual ones, represented by much better- and longer-known rocks, the types will not be designated systematically and definitively by the use of typal adjectives, but will be distinguished provisionally by prefixing to the magmatic name the name of a representative locality on the island.

CAMPTONOSE-AUVERGNOSE (FELDSPAR-BASALT), MONTE PONENTE TYPE

Megascopic characters.—In the hand specimen these rocks vary in color from a rather dark gray to black, and are sometimes compact but more often decidedly vesicular, highly scoriaceous forms being abundant. They are decidedly porphyritic, thin, tabular phenocrysts of white feldspar, from 2 to 4^{mm} long, being abundant, with fewer of olivine, 1 to 3^{mm} in diameter, usually pale yellow, but occasionally golden or rarely greenish, and still fewer of dark, greenish-black augite.

Microscopic characters.—In thin section the feldspar phenocrysts are seen to be wholly of labradorite, almost invariably twinned both according to the Carlsbad and the albite laws, the extinctions indicating a composition of about $Ab_1 An_1$. A zonal structure is rarely seen, the core being then more calcic, but the interior is not infrequently occupied by a sponge-like mass of inclusions, either of brownish glass or of augite and magnetite grains. The augite phenocrysts are rarely visible and present no features of special note. They are usually fragmentary or stoutly prismoidal, quite colorless, or less often pale gray, quite free from any zonal structure, and containing generally some inclusions of magnetite. The olivine phenocrysts, which are more abundant than those of augite, are colorless, usually highly euhedral, showing the common lozenge-shaped outlines, but occasionally with the edges corroded, especially on the faces of the domes and prisms. In most of the specimens the olivine phenocrysts are perfectly fresh, borders of iddingsite being extremely rare.

The ground-mass in which these lie is usually a typically intersertal one, thin tables of plagioclase, which has the same composition as that of the phenocrysts ($Ab_1 An_1$), being quite abundant and usually

[1] H. S. Washington, *American Journal of Science*, Vol. XXIV, 1907, p. 229.

divergently arranged. Between these feldspar laths is a granular aggregate of small, colorless augite anhedra, which are generally equant rather than prismoidal, and many opaque grains of magnetite, small grains of olivine and apatite prisms being rarely seen in the ground-mass. While some of the specimens seem to be holocrystalline, others are distinctly vitreous, and in these the femic constituents are not well crystallized, but are represented by dusty, dark specks, which render the ground-mass almost opaque. This is especially well seen in the rock which forms the dike at Monte Pozzolana. In this type nephelite seems to be rare or wholly wanting.

Mode.—The small size of the ground-mass constituents, especially of the augite and magnetite anhedra, and the great extent of overlapping, do not permit a satisfactory estimate of the mode by Rosiwal's method. But by making certain readjustments of the norm as calculated from the chemical analysis, the mode of the upper north flow of Monte Ponente was estimated to be approximately as follows:

Labradorite (Ab_1An_1)	57
Augite	26
Olivine	6
Magnetite (titaniferous)	10
Apatite	1
	100

The abundance of labradorite, and the relatively much greater amount of augite than of olivine, are the distinguishing features of this mode.

Chemical composition.—Two analyses of this type were made by me, one being of the uppermost, and the other of the lowest accessible, north flow of Monte Ponente. Parts of this latter flow showed a white mineral (gypsum) in the vesicles, but a specimen free from this was chosen for analysis. The gypsum itself will be described later. In this, as well as in the other analyses made of the basalts, especial attention was paid to the determination of titanium and nickel, the presence of which is so often disregarded, as these constituents have been found to be of considerable importance in considering the correlations of the Linosa rocks. Analysis No. II has been previously published,[1] but in a less complete form.

[1] H. S. Washington, *Quarterly Journal of the Geological Society*, Vol. LXIII, 1907, p. 75.

	I	II	Ia	IIa
SiO_2	48.06	48.84	0.801	0.814
Al_2O_3	15.90	14.62	0.156	0.143
Fe_2O_3	3.37	2.08	0.021	0.013
FeO	7.97	9.00	0.111	0.125
MgO	7.11	7.15	0.178	0.179
CaO	9.37	9.33	0.168	0.166
Na_2O	3.19	2.86	0.050	0.039
K_2O	0.85	0.89	0.009	0.010
H_2O+	0.40	0.49	.....	.....
H_2O-	0.06	0.07	.....	.....
CO_2	none	none	.....	.....
TiO_2	3.31	3.57	0.041	0.045
ZrO_2	....	none	.....	.....
P_2O_5	0.36	0.36	0.003	0.003
SO_3	....	0.05	.....	.....
Cl	0.14	0.42	0.002	0.006
Cr_2O_3	none	none	.....	.....
MnO	0.06	0.04	0.001	0.001
NiO	0.09	0.08	0.001	0.001
CuO	none	none	.....	.....
BaO	....	none	.....	....
SrO	....	0.04	.....	.....
	100.24	99.89		
O=Cl	.03	.09		
	100.21	99.80		

I. Auvergnose-camptonose (feldspar-basalt). Upper north flow of Monte Ponente, Linosa.

II. Auvergnose (feldspar-basalt). Lower north flow of Monte Ponente, Linosa.

Ia. Molecular ratios of I.

IIa. Molecular ratios of II.

The two analyses are very closely alike, there being no noteworthy difference between the uppermost and the lowermost flow. The small amounts of chlorine shown in these were extracted by water, and belong (with equivalent amounts of sodium) to salt derived from the sea-water, the waves of which break over the lavas. In the columns of molecular ratios these amounts of Na_2O (0.002 in I and 0.006 in II) have been deducted. The small amount of SO_3 in II indicates the practically complete absence of gypsum in the specimen analyzed. Among details to which attention may be called are the great preponderance of ferrous over ferric oxide, and the high figures for titanium dioxide and nickel oxide, features which will be discussed at length on a later page. The absence of copper, zirconium, chromium, and barium, and the presence of but traces of strontium, may also be noted.

Classification.—The norms of the preceding analyses, on which their classification according to the quantitative system depends, are shown in the adjoining table.

Norm of I		Ratios of I
Or	5.00	$\frac{Sal}{Fem}=\frac{58.17}{41.34}=1.41$. Class III, salfemane.
Ab	26.20	
An	26.97	$\frac{F}{Q,L}=\frac{58.17}{0}=\infty$. Order 5, gallare.
Di	13.63	
Hy	10.30	$\frac{K_2O+Na_2O}{CaO'}=\frac{59}{97}=0.61$. Rang 3, camptonase.
Ol	5.31	
Mt	4.87	$\frac{K_2O}{Na_2O}=\frac{9}{50}=0.18$. Subrang 4, camptonose.
Il	6.23	
Ap	1.00	
Rest	0.75	Symbol, III. 5. 4–3. 4.
	100.26	

Norm of II		Ratios of II
Q	1.44	$\frac{Sal}{Fem}=\frac{53.57}{44.79}=1.20$. Class III, salfemane.
Or	5.56	
Ab	20.44	$\frac{F}{Q}=\frac{52.13}{1.44}=36.20$. Order 5, gallare.
An	26.13	
Di	13.90	$\frac{K_2O+Na_2O}{CaO'}=\frac{49}{94}=0.52$. Rang 4, auvergnase.
Hy	20.03	
Mt	3.02	$\frac{K_2O}{Na_2O}=\frac{10}{39}=0.26$. Subrang 4–5, auvergnose.
Il	6.84	
Ap	1.00	
Rest	1.19	Symbol, III. 5. 4. 4–5.
	99.55	

It is evident that both fall well within the salfemane class and the perfelic order gallare, though a very small amount of quartz is present in the norm of II. As regards the rang, which is based on the relations of the alkalies to salic lime, I falls in the alkalicalcic division, camptonase, but so close to the border of the docalcic order auvergnase that it must be considered transitional. II falls within the docalcic order auvergnase, but it may be noted that this position is due to the abstraction of the soda to satisfy the chlorine, present as sodium chloride derived from sea-water, and that, were this not determined, the rock would fall also in the alkalicalcic order camptonase, where it was placed when this analysis was published previously. This rock must therefore also be regarded as transitional. The subrang is, in every case, distinctly sodic, so that I is to be called auvergnose-

camptonose, and II camptonose-auvergnose. Collectively, therefore, these rocks may be considered to belong to the transitional division camptonose-auvergnose, as they apparently tend to be docalcic.

Relations of norm and mode.—In these rocks the relations of norm and mode are quite simple and the readjustments needed to compute the latter from the former are confined almost wholly to those necessary to form the modal augite. As this mineral has not yet been analyzed, it is needless to go into any great detail, but it may be pointed out that these readjustments would, on the analogy of many other similar cases which have been worked out, consist in the transfer of a little of the normative anorthite, magnetite, and ilmenite, combined with the whole of the normative diopside, to the more complex modal augite molecule. The normative orthoclase, but little of which is present, must be considered as entering the modal plagioclase, though a small part of it may be present in the base of the ground-mass. As the augite is not markedly titaniferous, and the olivine presumably not more so, and as no titanium minerals, as perofskite, titanite, or ilmenite, are present, the very considerable amount of normative ilmenite (except that which enters the augite) must be held in the opaque ore grains, which, therefore, are to be considered as titaniferous magnetite.

But all of these readjustments are of comparatively small magnitude, even those needed for the formation of augite, which are moreover the normal ones, or those necessary in the case of the vast majority of igneous rocks, in which the pyroxene is aluminous. The modes are, therefore, normative and, in view of the abundance of feldspar phenocrysts, the Monte Ponente type may be briefly described as salphyro-camptonose-auvergnose, which indicates very concisely a basalt of about the chemical composition shown by the analyses, showing the mode in general described above, and with prominent feldspar phenocrysts.

The presence of a slight amount of quartz in the norm of II may seem to be inconsistent with the presence of olivine in the mode. But this is by no means uncommon, and instances of basalts containing olivine in the mode, while the norm shows none and even some quartz, are met with quite frequently, as along the Pacific slope of the United

States,[1] and in the fiescolal ciminose (ciminite) near Viterbo, which has been discussed elsewhere.[2] In such cases the analysis leaves no doubt that there is an excess of silica which, owing to the modal presence of olivine, must be increased in the mode over that shown by the norm, and is to be looked for either in the residual base of the groundmass or, as in the quartz-basalts, is present as clearly recognizable quartz.

Occurrence.—Basalts of this type are especially well represented at Monte Ponente, composing the extensive northern flows of this cone as well as the dike which cuts the tuff of Monte Pozzolana. Other representatives of the type are met with in many of the flows of Monte Vulcano, some of those of Monte Rosso and Monte Raneri, and in the basalts about the Scala Vecchia, which are probably derived from Monte Vulcano.

Gypsum in vesicles.—In parts of one of the lower flows of Monte Ponente, as noted above, the vesicles of the lava contain a white, crystalline substance, which was supposed to be a zeolite, in the field. Examination in the laboratory, however, shows that it is gypsum, and as such an occurrence is unusual for this mineral it merits a brief description.

The mineral forms thin crusts, which are distinctly crystalline, though no definite crystal forms are to be seen. It is soft (H = about 2), and slight crushing develops poorly defined cleavage flakes. Under the microscope these show rather low refraction and double refraction, which were not determined quantitatively. Two other cleavages are prominent (one better developed than the other), crossing at about 114°, that of the two minor cleavages of gypsum. The acute bisectrix lies in the acute angle of the cleavage rhomb, making angles with the cleavage trace parallel to $10\bar{1}$ varying from 12° 30′ to 14°, the corresponding angle for gypsum being 13° 39′. An analysis (on 0.2122^{gm}) gave the following results, the calculated values for gypsum being given for comparison:

[1] See, for instance, *Professional Paper*, U. S. Geological Survey, No. 14, 1903, p. 289, hessose, Nos. 18, 23, 29, and p. 333, auvergnose, No. 32. Many other cases could be cited from this collection.

[2] H. S. Washington, *The Roman Comagmatic Region*, Carnegie Publication No. 57, 1906, p. 64

	Found	Calculated
CaO.....	32.04	32.56
SO_3.....	46.61	46.51
H_2O.....	20.70	20.93
SiO_2.....	0.48	.....
Fe_2O_3.....	trace	.....
	99.83	100.00

The occurrence of gypsum in vesicles of basalts is not mentioned in the standard works of Zirkel, Rosenbusch, Roth, Iddings, and Levy and Lacroix, but its presence has been recorded in the vesicular lavas and the fumarole products of Vesuvius[1] and Etna,[2] and it is also mentioned as present in the boiling water of the crater lake of Graham's Island;[3] though, on the other hand, no mention is made of its presence at some other volcanoes, as Santorini and those of the Hawaiian Islands. It may also be mentioned that I did not find it in the very similar lavas of the Catalan volcanoes, nor is it recorded by Fernandez-Navarro in his very complete description of these lavas.[4] It also seems to be absent from the basalts of Pantelleria, not being mentioned by Foerstner,[5] nor having been observed by me.

CAMPTONOSE (FELDSPAR-BASALT), IL FOSSO TYPE

Megascopic characters.—In general these lavas are rather lighter in color than those of the preceding type, being mostly light to rather dark gray, decidedly black lava being rare. They are also more apt to be compact, and highly vesicular forms are less often met with. While they are porphyritic, phenocrysts are less abundant, this being especially noticeable in those of feldspar, which are very few, somewhat tabular, but furnishing rounded outlines in the hand specimen, and are usually rather large, up to 10^{mm} long and 5^{mm} wide, though very small and inconspicuous ones are also present. The phenocrysts of

[1] J. Roth, *Der Vesuv*, Berlin, 1857, p. 369; and J. L. Lobley, *Mount Vesuvius*, London, 1889, p. 287.

[2] Sartorius von Waltershausen, *Der Aetna*, Leipzig, 1880, Vol. II, p. 525.

[3] H. Abich, *Vulkanische Erscheinungen*, Braunschweig, 1841, p. 75.

[4] Cf. "Formaciones volcanicas de la Provincia de Gerona," *Mem. Soc. Espan. Hist. Nat.*, Vol. IV, 1907, pp. 437–43.

[5] E. Foerstner, *Boll. Com. Geol. Ital.*, 1881, p. 533.

olivine and of augite resemble those of the other type, both as to their characters and their amounts, and do not call for special mention.

Microscopic characters.—The general features shown in the thin section are much like those previously described, though there are some well-marked differences in the most representative specimens of this type. The very rarely seen feldspar phenocrysts are of a labradorite, highly twinned, of about the composition Ab_1An_1, as in the previous case, and similarly no constant difference of any importance can be detected in the characters of the phenocrysts of augite and olivine, though those of the latter are more abundant than in the Monte Ponente type.

The ground-mass, on the other hand, offers more points of difference. Small tabular, highly euhedral crystals of labradorite are abundant, but they are usually shorter and stouter than in the other rocks, and the arrangement, instead of being diverse, is typically subparallel, giving rise to well-marked flow textures, which are especially clearly developed in the blocks from the tuffs. Olivine is rarely seen in the ground-mass, and the anhedra of augite and magnetite are closely like those described above. The abundance of dark, dusty grains is seen only in one or two cases, and these transitional toward the preceding type, but the interstitial, colorless base is here less apt to be isotropic and often shows a faint birefringence, indicating the presence of the nephelite shown in the norm. Its amount, however, is never very great.

Mode.—Owing to the impossibility of a satisfactory application of the Rosiwal method, the mode of the specimen analyzed was estimated by readjustment from the norm, and is approximately as in I below, that of the other type being repeated in II for comparison.

	I	II
Labradorite (Ab_1An_1)	50	57
Nephelite	5	0
Augite	20	26
Olivine	14	6
Magnetite (titaniferous)	10	10
Apatite	1	1
	100	100

It will be seen that the relative amounts of salic and of alferric and femic minerals is about the same in the two, so that the ground-mass of the Fosso type must be more highly feldspathic than that of the Ponente type, much of the feldspar of which exists as phenocrysts, and this fact will account for the usually lighter color of the present rock. The amount of nephelite is small, and those of augite, magnetite, and apatite scarcely differ in both rocks, while olivine is distinctly higher in that from Il Fosso.

Chemical composition.—This was determined by the analysis of a specimen from a block in the tuffs of Il Fosso, the results of which are given below, along with the molecular ratios.

SiO_2	46.55	0.776
Al_2O_3	14.55	0.143
Fe_2O_3	3.17	0.020
FeO	7.88	0.110
MgO	8.61	0.215
CaO	8.75	0.156
Na_2O	3.71	0.060
K_2O	1.62	0.017
H_2O+	0.14	.....
H_2O-	0.03	.....
CO_2	none	.....
TiO_2	3.84	0.048
P_2O_5	0.55	0.004
MnO	0.10	0.001
NiO	0.12	0.001
	99.62	

Camptonose (feldspar-basalt). Block in tuff, Il Fosso, Linosa.

The general features of this analysis are closely like those of the two Monte Ponente rocks, even in the small details of titanium, manganese, and nickel. It may be noted, however, that this rock is very distinctly lower in silica and higher in alkalies, especially potash, while magnesia is a trifle higher and lime slightly lower, the other constituents remaining about the same.

Occurrence.—The most representative specimens of this type were met with as angular, compact blocks in the tuffs of Monte Levante, Il Fosso, and the north crater of Monte Bandiera, while other specimens, decidedly transitional toward the preceding type, occur as flows at Monte Vulcano and in the blocks of lava, apparently derived from Monte Ponente, which have been excavated at the Scala Nuova for use in building the jetty.

Classification.—The norm of this rock, calculated from the figures shown in the analysis, is as follows:

Norm		Ratios	
Or	9.45	$\frac{Sal}{Fem}=\frac{55.52}{43.86}=1.27$.	Class III, salfemane.
Ab	23.32		
An	18.35	$\frac{F}{L}=\frac{51.12}{4.40}=11.62$.	Order 5, gallare.
Ne	4.40		
Di	17.05	$\frac{K_2O+Na_2O}{CaO'}=\frac{77}{66}=1.17$.	Rang 3, camptonase.
Ol	13.53		
Mt	4.64	$\frac{K_2O}{Na_2O}=\frac{17}{60}=0.28$.	Subrang 4, camptonose.
Il	7.30		
Ap	1.34	Symbol, III. 5. 3. 4.	
Rest	0.39		
	99.77		

This rock, therefore, falls well within the salfemane class, the amount of nephelite being negligible, and it is also clearly in the perfelic order, the alkalicalcic rang, and the dosodic subrang, and is thus an almost central camptonose.

The relations of the norm and mode, which are almost identical with those discussed above, need not be repeated here. The mode may be considered as normative, and the type may be briefly described as an alferfemphyro-camptonose.

CAMPTONOSE (OLIVINE-BASALT), MONTE RANERI TYPE

Megascopic characters.—This type differs from the preceding in the abundance and size of the olivine phenocrysts, which are olive-green in color, from 2 to 10^{mm} in diameter, and constitute at least 20 per cent. of the rock. Feldspar phenocrysts are tabular, as in the salphyric subtype just described, but their number is very few, and they are small and inconspicuous, as are also the phenocrysts of augite. Most of the specimens of this type which were collected are compact, but scoriaceous and vesicular forms also occur. On weathering, the compact forms show a feature which was also noted in some of the Catalan basalts, namely a peculiar mottled appearance in patches of dark and light gray, or dark gray and slightly reddish gray, the rock tending also to disintegrate into small, angular pieces which correspond to these colored areas. This appearance, which has been called *Sonnenbrand* by German quarrymen, is not uncommon

in some basalts, especially in those which contain nephelite, and has been attributed by Leppla[1] to the presence of this mineral.

Microscopic characters.—In thin section the same minerals are seen to be present as in the preceding type but, corresponding to the megascopic characters, olivine phenocrysts are much more numerous. These are seldom euhedral, but usually present rounded outlines, which are frequently irregular, though embayments, such as are often ascribed to corrosion by the magma, are rare. The olivine phenocrysts carry some small inclusions of magnetite, and are occasionally slightly brown on the edges through incipient alteration. The few feldspar phenocrysts are of labradorite, about Ab_1An_1, thick tabular in shape, and frequently spongy in the interior through the presence of many inclusions of glass, augite, and magnetite. No augite phenocrysts were seen in the sections examined.

The ground-mass is somewhat coarser than in the preceding type, and the abundant, highly euhedral, labradorite tables are shorter and stouter, and an intersertal arrangement is not so pronounced. Small anhedra of colorless or yellowish augite and of magnetite are abundant, while small anhedra of colorless olivine are present in the ground-mass to a greater extent than in the preceding type, though they must be considered as but accessory ground-mass constituents. A glass base seems to be present occasionally, but its amount is very small.

Mode.—While no satisfactory estimate of the mode by Rosiwal's method was possible, the relative amounts of the various minerals present was readily estimated by some simple readjustments of the figures shown by the norm, which are given on a later page. The mode is approximately as follows:

Labradorite (Ab_1An_1)	47
Augite	11
Olivine	28
Magnetite (titaniferous)	10
Apatite	1
Glass and nephelite	3
	100

As compared with the modes of the preceding types it is clear that the most marked difference lies in the amounts of augite and

[1] A. Leppla, *Zeitschrift der praktischen Geologie*, Vol IX, 1901, p. 175.

olivine, the proportions of these being reversed. In the Monte Raneri type, also, the amount of labradorite is somewhat less than in the preceding rocks, while the ores and apatite remain about the same.

Chemical composition.—The results of an analysis made of the freshest specimen from Monte Raneri are here given. As compared

SiO_2	45.75	0.763
Al_2O_3	13.98	0.137
Fe_2O_3	3.23	0.020
FeO	8.02	0.111
MgO	14.69	0.367
CaO	7.11	0.127
Na_2O	3.10	0.050
K_2O	1.10	0.012
H_2O+	0.16	.....
H_2O-	0.04	.....
CO_2	none	.....
TiO_2	2.90	.036
P_2O_5	0.36	0.003
Cr_2O_3	trace	.....
MnO	0.06	0.001
NiO	0.14	0.002
	100.64	

Camptonose (olivine-basalt). Monte Raneri, Linosa.

with those of the preceding types the silica is decidedly lower than the lavas of Monte Ponente, but only slightly lower than the block from Il Fosso. Alumina, the oxides of iron, the alkalies, titanium, phosphorus, and manganese are almost the same; but lime is considerably lower, and magnesia, on the other hand, very much higher, these last features being in accord with the great abundance of olivine in this type and its comparative paucity in augite. Nickel also seems to be present in somewhat greater amount, and this is to be expected on account of the high content in magnesia, though the small figures are not very significant. Only a mere trace of chromium is present, and none of this was detected in the other rocks analyzed.

Occurrence.—Typical examples of this rock were found only at Monte Raneri, where they seem to be the prevailing type, but a very similar lava was met with as blocks at Monte Rosso, in which, however, the olivine phenocrysts, while prominent, are fewer and smaller than in the Monte Raneri rock.

Classification.—The norm and ratios of the specimen analyzed are as follows:

Norm		Ratios
Or	6.67	$\frac{Sal}{Fem}=\frac{51.80}{48.54}=1.07$. Class III, salfemane.
Ab	22.01	
An	20.85	$\frac{F}{L}=\frac{49.53}{2.27}=21.81$. Order 5, gallare.
Ne	2.27	
Di	9.26	$\frac{K_2O+Na_2O}{CaO'}=\frac{62}{75}=0.83$. Rang 3, camptonase.
Ol	28.17	
Mt	4.64	$\frac{K_2O}{Na_2O}=\frac{12}{50}=0.24$. Subrang 4, camptonose.
Il	5.47	
Ap	1.00	Symbol, III. 5. 3. 4.
Rest	0.40	
	100.74	

From the figures given it appears that this type falls well within all the magmatic divisions, and that it is a typical camptonose. The classificatory influence of the very high magnesia, in which respect it differs most widely from the other rocks analyzed, would be expressed in the minor divisions of the system, especially in the section of grad, which is based on the relations of olivine to pyroxene. But in the present introductory stage of the new system it is not deemed advisable to carry the classification as far as these minor divisions for ordinary purposes, since the main features of a rock may be quite clearly expressed by the use of the major magmatic divisions alone (from class to subrang inclusive), together with a typal qualifier or adjectival prefixes, to indicate the mode and texture.

So far as the relations of norm and mode are concerned, the readjustments needed to derive the mode from the norm are of slight importance, being confined chiefly to the augite, the amount of which is small, as we have seen above. The mode may therefore be considered as normative, and the rock may be described as an olivine-phyro-camptonose, which designates very concisely its mode, texture, and chemical composition. In the prevailing systems of classification it is an olivine-feldspar-basalt, but the use of a special name would be needed if it were desired to indicate the size and abundance of olivine phenocrysts, in which respects it differs from many others.

THE TUFFS

While volcanic tuffs, as a rule, offer few features of interest, yet as those of Linosa are so abundant and play such a conspicuous rôle in the formation of the cones of the earlier period, they may be described briefly.

These tuffs vary in color from dark, rather greenish, gray to a light brownish yellow. In some cases only one of these is present, as yellow tuffs at Monte Pozzolana and Monte Biancarella, or dark gray at the main ridge of Monte Bandiera; while elsewhere both varieties are met with, as at the two craters east of Monte Bandiera and at Monte Levante. As will be seen later, the differences between the two are probably to be ascribed only to differences in the progress of alteration.

The dark-gray tuffs are very fine grained and friable, readily rubbing down to an impalpable powder, at least in great part. Aside from the large blocks of lava which are embedded in them, they contain very small fragments of black basalt, seldom larger than a pea and running down to very small angular grains. A bedded structure is generally clearly manifest, and is frequently emphasized by thin layers more rich in the small fragments of basalt. Unfortunately, no sections were made of these, but the powder, when viewed under the microscope, shows fragments of colorless augite as the only recognizable mineral, the greater part of the mass being a dust of almost opaque, but apparently isotropic, minute grains, probably of glass.

The yellow tuffs[1] show, likewise, small pieces of black basalt, often vesicular, which stand out against the light-yellow background more prominently than do those in the gray tuff. The yellow portion is rather less friable than the preceding, and is somewhat porous, the constituent grains being agglomerated into very small, rounded aggregates, a millimeter or less in diameter, between which there are numerous crevices and pores. The powder of this, under the microscope, also reveals small fragments of augite, the light-yellow dust in which they lie being semi-transparent and apparently isotropic.

The chemical composition of these tuffs is shown in the two analyses given below, both analyses being made of average material which

[1] These are the trachytic rocks of Calcara.

includes the very small fragments of basalt which seem to be always present. They were made on air-dried material, the specimens having been kept in a drawer for over a year prior to the analysis. None of the minor constituents, except titanium dioxide, were determined, but both manganese and nickel were present, and apparently in amounts comparable to those shown by the preceding analyses.

	I	II	I*a*	II*a*
SiO_2	47.43	39.00	50.16	46.66
Al_2O_3	17.20	15.58	18.19	18.64
Fe_2O_3	4.2[illegible]	6.13	4.44	7.33
FeO	5.27	3.11	5.57	3.72
MgO	4.85	6.55	5.13	7.83
CaO	7.56	6.82	8.00	8.16
Na_2O	3.53	3.22	3.73	3.85
K_2O	1.51	0.59	1.60	0.71
H_2O+	2.42	6.03	....	....
H_2O-	3.12	8.18	....	....
CO_2	none	1.83	....	....
TiO_2	3.00	2.59	3.17	3.10
	100.09	99.63	99.99	100.00

I. Gray tuff. Monte Levante, Linosa.

II. Yellow tuff. Monte Pozzolana, Linosa.

I*a*. Analysis I calculated free from water.

II*a*. Analysis II calculated free from water and carbon dioxide.

These analyses present some features of interest. The silica of I is about the same as that of the lavas, while that of II is very much lower. Also the alumina of I is distinctly higher than in the lavas,[1] while that of II is about the same as in these. In view of the evidently very considerable weathering which these tuffs have undergone, the much lower ratio of ferrous to ferric oxide, as compared with the figures shown by the fresh lavas, is not surprising. Magnesia is very decidedly lower in I than in the majority of the lavas, while in II it is but slightly so, but the figures for lime as well as for the alkalies and titanium dioxide do not differ materially from those in the fresh rocks. The presence of considerable water only driven off at a high temperature, and of carbon dioxide in II, is readily understood, but the high

[1] This high alumina, taken in connection with the low magnesia, might be thought to be due to the common analytical error of partial precipitation of the magnesia with the alumina, owing to the presence of insufficient ammonium chloride. But this was specially guarded against, and the absence of magnesia from the precipitate by ammonium hydroxide was definitely proven.

figures for water which is driven off at 110°, and which cannot be due only to the moisture of the sample, indicates the presence of a zeolitic cement, the amount of which must be very large in the yellow tuffs, in which calcite also is present, and which serves to explain their more coherent character.

While the processes involved in weathering are highly complex and involve the abstraction of certain constituents, and to a less extent the addition of others, and in varying amounts for each,[1] so that the calculation of the figures shown by the analysis of weathered rocks to a water- and carbon-dioxide-free basis cannot usually express the original composition of the mass, yet the figures shown in the last two columns, which have been calculated on this basis, are not without interest. In spite of the higher alumina and ferric oxide, and lower ferrous oxide and magnesia, which they show, they indicate that the tuffs are derived from basalts which did not originally differ chemically very materially from the later lavas, especially those of the Monte Ponente type. The scarcely appreciable change in the figures for the alkalies, however, those for soda being even slightly higher in the tuffs than in the lavas, would indicate that the original magma of the tuffs was distinctly higher in these, especially in soda, and that nephelite would probably have been present in considerable amount had they formed compact lavas. The somewhat higher soda in the blocks of lava from the tuffs (page 23), over those of the later lava flows, leading to the presence of nephelite in the norm, and probably in the mode, of these rocks, also points the same way.

In general, however, regarding the tuffs as weathered representatives of original basaltic ones, the processes of alteration seem to have been normal, as explained by Roth[2] and Merrill,[3] the latter especially pointing out the usually more rapid loss in magnesia than in lime.

Although the figures shown in I*a* and II*a* above are open to the criticism that they do not adequately represent the original magmas, yet it is instructive to examine the norms which they yield, which are given here, the ratios being omitted.

[1] Cf. G. P. Merrill, *Rocks, Rock-weathering, and Soils*, New York and London, 1897, pp. 173–94.

[2] J. Roth, *Allgemeine und chemische Geologie*, Vol. III, 1893, p. 251.

[3] G. P. Merrill, *op. cit.*, pp. 218–24, 239.

	I*b*	II*b*
Or	9.45	3.89
Ab	31.44	31.16
An	28.08	31.69
Ne	....	0.71
Di	9.17	6.91
Hy	8.16	....
Ol	1.18	11.48
Mt	6.50	2.78
Il	6.08	5.93
Hm	....	5.44
	100.00	99.99

I*b*. Norm of I*a*, gray tuff of Monte Levante.
II*b*. Norm of II*a*, yellow tuff of Monte Pozzolana.

From these figures the gray tuffs, or rather the original rock on the assumption that the recalculated analysis correctly represents it, falls in the subrang andose (II. 5. 3. 4), while the original rock of the yellow tuff would fall in beerbachose (II. 5. 3. 5), but so close to the border of the docalcic order that it is nearly in hessose (II. 5. 4. 4–5), so that it should be called a hessose-beerbachose (II. 5. 4–3. 4–5). The most salient feature about these magmatic positions is the fact that, differing from the fresh lavas, these tuffs are in the dosalane class, not the salfemane. This position is brought about, in part by the high alumina, which increases the amount of normative anorthite, in part by the greater amount of ferric oxide relative to ferrous, and by the lower magnesia, both of which decrease the amounts of femic minerals. But apart from these differences of class, the rocks of the tuffs would seem to have been closely concordant, as far as the order, rang, and subrang are concerned, with the later lavas, and they were probably originally also in the salfemane class.

GENERAL PETROLOGICAL RELATIONS

Character and succession of the lavas.—The figures shown by the analyses, and the facts in regard to the relative ages of the various volcanic cones, presented in the preceding pages, furnish us with the data for a brief discussion of the general characters of the Linosa lavas, and their order of succession. For convenient reference all of the analyses of the lavas are repeated here, those of the tuffs being omitted, as their original characters are so obscured by weathering as to render these analyses of little use. There are also given in the

table some analyses of closely related rocks from Pantelleria, Sardinia, and Catalonia, which have already been published,[1] and which will be referred to in the subsequent discussion.

The lavas of Linosa would seem to be quite monotonous in chemical as well as mineral characters. Mineralogically they are of very simple composition, labradorite, augite, olivine, titaniferous magnetite, and apatite being the only minerals present in all cases, and usually in about this order of abundance, though in one rare type the amount of olivine surpasses that of the augite. Chemically, they are

	I	II	III	IV	V	VI	VII	VIII	IX
SiO_2....	48.06	48.84	46.55	45.75	46.22	44.83	52.40	52.67	47.66
Al_2O_3..	15.90	14.62	14.55	13.98	12.23	11.73	15.26	15.35	14.36
Fe_2O_3..	3.37	2.08	3.17	3.23	4.91	1.35	0.74	3.82	2.83
FeO....	7.97	9.00	7.88	8.02	7.71	11.79	8.33	5.42	8.44
MgO...	7.11	7.15	8.61	14.69	6.74	5.50	7.45	4.40	8.19
CaO....	9.37	9.33	8.75	7.11	9.86	9.63	7.33	5.91	9.36
Na_2O...	3.19	2.86	3.71	3.10.	3.39	3.34	3.54	4.50	3.51
K_2O....	0.85	0.89	1.62	1.10	1.13	1.40	0.99	2.68	1.54
H_2O+ .	0.40	0.49	0.14	0.16	0.17	0.81	0.29	0.37	0.17
H_2O- .	0.06	0.07	0.03	0.04	0.05	0.10	0.06	0.14	0.20
CO_2....	none	none	none	none	none	none	none	none	none
TiO_2...	3.31	3.57	3.84	2.90	5.68	6.88	3.12	4.04	3.83
P_2O_5...	0.36	0.36	0.55	0.36	1.46	2.14	0.49	0.75	0.45
MnO...	0.06	0.04	0.10	0.06	....	....	0.08	....	....
NiO....	0.09	0.08	0.12	0.14	....	....	0.06	....	....
	100.24	99.89	99.62	100.64	99.55	99.50	100.14	100.05	100.54

I. Auvergnose-camptonose (III. 5. 4–3. 4) [feldspar-basalt]. Upper north flow, Monte Ponente, Linosa. Includes Cl 0.14, CuO none.

II. Auvergnose (III. 5. 4. 4, 5) [feldspar-basalt]. Lower north flow, Monte Ponente, Linosa. Includes SO_3 0.05, Cl 0.42, SrO 0.04, and ZrO_2, CuO, and BaO none.

III. Camptonose (III. 5. 3. 4.) [feldspar-basalt]. Block in tuff, Il Fosso, Linosa.

IV. Camptonose (III. 5. 3. 4) [olivine-basalt]. Monte Raneri, Linosa. Includes trace of Cr_2O_3.

V. Camptonose (III. 5. 3. 4) [feldspar-basalt]. Monte San Elmo, Pantelleria.

VI. Camptonose (III. 5. 3. 4) [feldspar-basalt]. Island of 1891, near Pantelleria.

VII. Camptonose (III. 5. 3. 4) [feldspar-basalt]. Near Cuglieri, Sardinia.

VIII. Akerose (II. 5. 2. 4) [feldspar-basalt]. Monte San Mateo, near Ploaghe, Sardinia.

IX. Camptonose (III. 5. 3. 4) [feldspar-basalt]. Castellfullit, near Olot, Catalonia, Spain.

[1] H. S. Washington, *Quarterly Journal of the Geological Society*, Vol. LXIII, 1907, p. 75.

characterized by rather low silica and alumina, high iron oxides, with ferrous oxide largely predominating over ferric, rather high magnesia and lime, the former being very high in the olivine-rich type, rather high soda (for such femic rocks), and low potash, very high titanium dioxide, small amounts of phosphoric pentoxide and manganese, and finally the constant presence of nickel oxide in rather high amounts for this constituent. Zirconium, chromium, copper, barium, and strontium seem to be either uniformly absent or present only in traces.

As regards the succession, or order of eruption, of the lavas, their uniform and monotonous character in general gives little scope for distinctions. From the figures furnished by the analyses of the tuffs and the blocks of the cones of the earlier period, however, as compared with those of the later lavas, it would seem that the earlier rocks were slightly higher in soda, and in general somewhat lower in silica and possibly in lime, than the later ones. The iron oxides, potash, titanium, and phosphorus apparently change but little, while there are indications of a slight drop in magnesia, though the high figure for this constituent in the Monte Raneri lava (which, however, is earlier than those of Monte Ponente) is anomalous. But the figures show, in general, variations of too slight an extent to justify any definite conclusion that a decided change has taken place, and indicate, on the contrary, that the chemical character of the magma has remained practically the same from the earliest eruption on Linosa to the latest. It is possible that this is connected with a short period of volcanic activity on the island, or it is possibly indicative of this. In the absence of any geological or stratigraphical means of measuring the time elapsed since the first eruptions, the interval between those of the tuff and of the lava cones, and the time that has passed since the last volcano became extinguished, we are not in a position to decide.

Relations of the Linosa lavas to others.—In a paper[1] published some years ago a possible genetic connection was suggested between the lavas of Linosa, Pantelleria, and Sardinia, the suggestion being based on the few analyses of the rocks of Pantelleria and Sardinia which had been published at that time, none of Linosa being known, as well as on some more general tectonic grounds. In a more recent

[1] H. S. Washington, *American Journal of Science*, Vol. VIII, 1899, p. 293.

paper,[1] based on numerous analyses which had been made of material collected during the trip on which Linosa was visited, especially of the basalts, the same idea was again expressed, the rocks of Catalonia being also considered as related to those of the other localities, and the probable existence of a distinct comagmatic region (petrographic province) in the western Mediterranean being pointed out. While this conclusion is based partly on the character of the basalts, there is considerable other evidence in its favor in the characters of the more salic rocks, and in other facts, but a full discussion must await the publication of the whole series of analyses, many of which remain to be made. In the present place it must suffice to point out the similarities between the basalts along this zone.

Turning to the table of analyses on page 32, it will be seen that the chemical characters of the basalts of Pantelleria, Sardinia, and Catalonia (only a few of which have been given here) are remarkably similar to those of Linosa and of each other. Except in Sardinia, where it is somewhat higher, silica is about the same in all, and the figures for the other constituents present close analogies with each other. This is especially well seen in those for the oxides of iron, ferrous oxide largely predominating over ferric, and those for titanium dioxide, the figures for this constituent, which reach a maximum at Pantelleria, being the highest known to me for any such large series of rocks. Also these basalts are highly dosodic, and in this respect in marked contrast to the salfemic rocks of the Italian peninsula, in which potash is abundant and is greatly in excess over soda, giving rise to the highly leucitic rocks for which the Bolsena-Vesuvius line of volcanoes is so famous.

While the general resemblance, and hence the probable genetic connection, between the basalts of Linosa, Pantelleria, Sardinia, and Catalonia are thus clear, it is noteworthy that the general monotony of the lavas of Linosa is in marked contrast with the conditions that obtain on the neighboring island of Pantelleria, as well as on Sardinia. On these two islands the earlier eruptions were of highly salic rocks, phonolites, trachytes, and rhyolites in the older classifications, being followed by, and the era of vulcanicity closing with, the eruption of

[1] H. S. Washington, *Quarterly Journal of the Geological Society*, Vol. LXIII, 1907, p. 69.

more femic rocks (basalts), which formed small cinder cones similar to those of Linosa. It might be argued from this that the last eruptions of Linosa belong to a very recent date, subsequent to those of the earlier salic lavas of Pantelleria, and possibly contemporaneous with those of the final basaltic cones of this island. And this view is strengthened by consideration of the very recent submarine eruptions of 1831 and 1891 in the neighborhood of Pantelleria, the lavas of which are highly femic, and resemble those of Linosa and the last eruptions of Pantelleria.

THE POST-JURASSIC IGNEOUS ROCKS OF SOUTHWESTERN NEVADA[1]

SYDNEY H. BALL

INTRODUCTION

Three mighty periods of igneous activity mark the geological history of southwestern Nevada and eastern California. The latest of these, the Tertiary, has been ably treated by Spurr[2] while concerning the earliest, the pre-Cambrian, we know little. It is the purpose of this article to describe briefly the period of igneous activity beginning in post-Jurassic time and ceasing long prior to the Eocene.

During the field season of 1905 the writer made a reconnaissance of some 8,500 square miles in southwestern Nevada and eastern California for the United States Geological Survey.[3] This area lies between 36° 30′ and 38° North latitude and 117° 30′ and 116° West longitude (see Fig. 1).

GENERAL STATEMENT

The earliest of the post-Jurassic igneous rocks recognized in the area are the granular siliceous intrusive rocks; next came the intrusion of quartz-monzonite porphyry, poor in ferromagnesian minerals, while the youngest of the pre-Tertiary rocks are diorite and diorite-porphyry.

DISTRIBUTION

The post-Jurassic igneous rocks are widely distributed over the area under consideration although they cover larger expanses in its western portion, and are the predominant formation from longitude 117° 30′ westward to the Sierra Nevada. The Tertiary lavas and sedimentary rocks and the Pleistocene and Recent terrestrial deposits cover vast stretches so that a cursory examination of a geological map of Nevada gives but little idea of the importance of

[1] Published with the permission of the Director of the U. S. Geological Survey.

[2] J. E. Spurr, *Journal of Geology*, Vol. VIII, pp. 621–46.

[3] See *Bull. U. S. Geological Survey No. 308.*

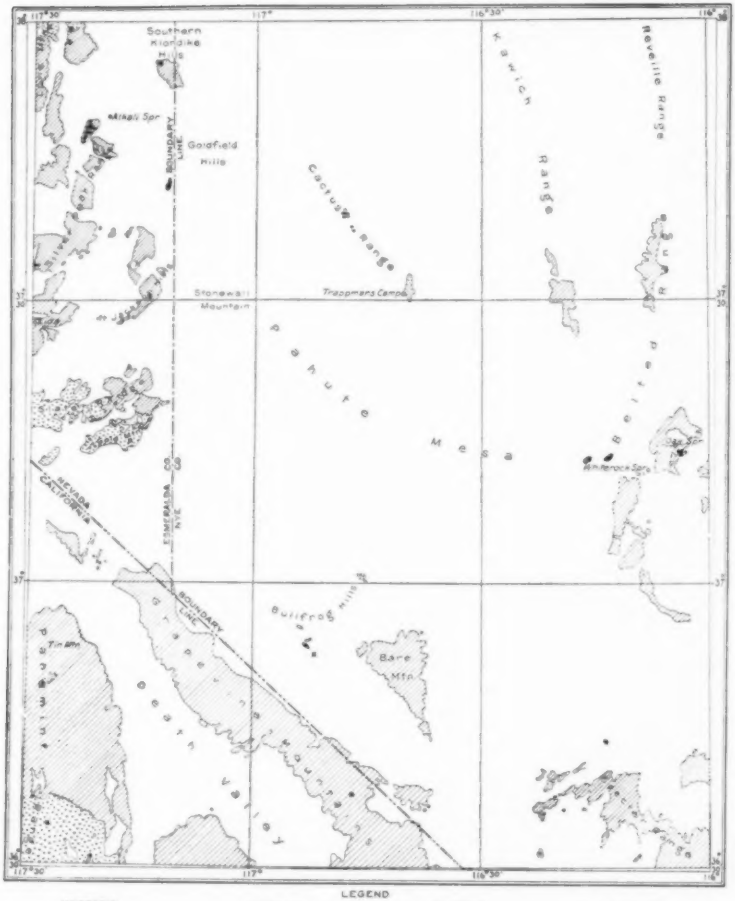
Southern Klondike Hills
Goldfield Hills
BOUNDARY LINE
Cactus Range
Kawich Range
Reveille Range
Stonewall Mountain
Troopmans Camp
Rhodes Mesa
Bullfrog Hills
Bare Mtn.
Death Valley
NEVADA
CALIFORNIA
LEGEND
PALEOZOIC SEDIMENTARY ROCKS
POST-JURASSIC GRANULAR SILICEOUS ROCKS
POINTS AT WHICH DIORITE AND DIORITE-PORPHYRY OCCUR
TERTIARY AND QUATERNARY ROCKS
SCALE IN MILES
0 5 10 15 20 25 30 35

FIG. 1

the post-Jurassic igneous intrusives. But when we consider only the region at present covered by pre-Tertiary formations we find that the widely distributed masses of post-Jurassic igneous rocks form approximately one-sixth of this territory. Moreover, at many places where Tertiary lavas mask the older formations, fragments of pre-Tertiary igneous rocks are included in the lavas, thus showing the presence of these older rocks on the sides of the conduit through which the molten Tertiary rock welled.

THE GRANULAR SILICEOUS SERIES

GENERAL STATEMENT

This series is composed of four rocks which were intruded in the following order; monzonite and quartz-monzonite porphyry; granular rocks, including granite, quartz-monzonite, and soda syenite; aplites and pegmatites. These rocks in each separate batholith solidified successively from a single magma in the reverse order of their acidity.

MONZONITE AND QUARTZ-MONZONITE PORPHYRY

The granular igneous rocks of the Belted and Panamint ranges, of Pahute Mesa, and of Gold Mountain Ridge, contain fragments of fine-grained gray monzonitic rocks. That of Gold Mountain is a quartz-monzonite porphyry in which the ferromagnesian mineral is biotite. A specimen from the Belted Range is a basic hornblende-biotite-monzonite. These monzonites, while somewhat older than the granular siliceous rocks in which they occur, are massive and are believed to be a somewhat earlier crystallization of the magma from which the more siliceous rocks afterward solidified.

GRANITES, QUARTZ-MONZONITE AND SODA-SYENITE

Petrographic character.—These rocks range on the one hand from alaskite through muscovite-, muscovite-biotite-, and biotite-granite to a quartz-monzonite approaching granodiorite, and on the other hand from normal granite through soda-rich granite to soda-syenite. Most of these rocks grade into corresponding porphyries. The lithologic character of the rocks of most of the areas shown on the map (see Fig. 1) is usually rather constant, although in the Gold Mountain Ridge granite-porphyry grades into hornblende-bearing quartz-monzonite porphyry in a distance of only ten feet.

Many of these rocks are characterized by large porphyritic feld-

spars. The granite at Oak Spring in the Belted Range contains phenocrysts of feldspar, quartz, and biotite which reach maximum lengths of 4 inches, ½ inch, and 1 inch respectively. The feldspar phenocrysts are locally sufficiently abundant to form one-third of the rock mass. The microscopic character of the granular siliceous rocks are tabulated in Table I, and those of the corresponding porphyries in Table II.

From the east to the west edge of the area under consideration the rocks in the main become progressively less siliceous and the quartz-monzonite of the Panamint Range approaches in composition the granodiorite of the Sierra Nevada. In a broad way then the magmas in the various centers of igneous activity were less and less siliceous from meridian 116 west to the Sierra Nevada. There is also a slight increase in the soda content of the rocks from the eastern border of the area to the western.

The soda-syenite and soda-syenite porphyry which form a small mass intrusive in Pennsylvanian limestone 11½ miles southeast of Tin Mountain (Panamint Range) are worthy of more detailed description. The soda-syenite is characterized by abrupt and great changes in granularity and in the relative abundance of the constituent minerals. The most common type is a coarse to medium-grained gray rock composed of predominant gray with some pink feldspar, subordinate greenish-black amphibole or pyroxene, and biotite. Many of the feldspars have good crystal outlines and in the more porphyritic facies the abundant feldspar laths which have lengths of 1½ inches are aligned in flow orientation. The rock, next to the limestone, is very fine grained. Epidote has developed at the expense of the ferromagnesian minerals in all facies. Under the microscope this rock proves to be a soda-syenite or nordmarkite of uneven hypidiomorphic granular texture. Alkali feldspars are the predominant constituents and include the species orthoclase, microperthite, and anorthoclase. With these is a little oligoclase. The alkali feldspars form rude tabular crystals, many of which are twinned according to the Carlsbad law. Augite sometimes occurs in columns, or anhedra of augite, green hornblende, quartz, biotite, and yellowish-brown garnet may lie between these tabular forms. The augite shows characters approaching aegirite-augite. The

accessory minerals are titanite, magnetite, apatite, and fluorite. Fluorite flecks the alkali feldspar and was probably introduced by magmatic gases.

The soda-syenite is cut by dikes of a compact greenish-gray aplite. Pink feldspar is associated with the gray feldspar, and some veins are composed wholly of pink feldspar with pyroxene. Under the microscope the aplite has a very uneven-grained, allotriomorphic texture. The feldspars include microperthite, orthoclase, and some anorthoclase; a little quartz is also present. Although the rock is not rich in ferromagnesian minerals, there are many small grains and partial crystals of aegirite-augite, which show the usual zonal structure, with deeper green bands on the border. Irregular grains of a light-yellow garnet are rather abundant and titanite and apatite are accessories. Fluorite occurs in small blebs, surrounded by a mesh of sericite shreds, which were probably formed by the same gases that deposited the fluorite. Calcite is also present and its contacts with other minerals are so sharp that it was probably deposited in miarolitic openings. The contact between the aplite and the syenite is in some cases sharp, in others gradational. In one instance a dike of syenite porphyry is faulted along an aplitic dike, but there is little doubt that the two are genetically related. Narrow pegmatitic dikes, the feldspar and pyroxene of which reach a diameter of 1 inch, also occur.

The soda-syenite intrudes Pennsylvanian limestone and has suffered the same deformation as the quartz-monzonite which lies to the south of it (No. 11, Table I). Phases of the pegmatite of the monzonite closely resemble the soda-syenite in mineral composition and from this fact and the proximity of the two masses the soda-syenite is believed to be a later differentiation of the monzonitic magma. At places the pegmatite of the monzonite has a border composed of almost pure augite with a median band of feldspar. The boundary planes are rather distinct although individual crystals extend from the monzonite into the basic bands and from these into the acidic center. The more siliceous portion shows under the microscope the composition of a soda-syenite, and consists of orthoclase, anorthoclase, augite, hornblende, oligoclase, quartz, titanite, magnetite, apatite, and zircon. Titanite occurs both in well-crystallized wedges

TABL

GRANULAR SILI

Name and Place..	Alaskite Bullfrog	Muscovite-granite Southern Klondike	Biotite-muscovite-granite Trapmann's Camp, Pahute Mesa	Biotite-granite Slate Ridge	Biotite-granite Gold Mountain, West End
Texture	Allotriomorphic	Allotriomorphic	Allotriomorphic	Allotriomorphic	Hypidiomorphic
Granularity	Medium	Fine	Fine to medium	Coarse	Fine
Quartz	Essential	Predominant	Essential	Essential	Predominant
Orthoclase	Essential	Essential	Predominant	Predominant	Essential
Micropegmatite	Present				
Microperthitic intergrowth					
Microcline	Present	Present			
Oligoclase		Present	Essential		Essential
Muscovite	Secondary	Essential	A little, both original and secondary		*x*
Biotite	Present		Essential	Essential	Essential
Hornblende					
Augite					
Titanite					*x*
Apatite	*x*[1]				*x*
Zircon	*x*		*x*	*x*	*x*
Magnetite	*x*			*x*	*x*
Allanite					

[1] Symbol *x* indicates that the mineral is present as an accessory.

TABL

PORPHYRITIC ROCKS OF GRANU

Name and place	Granite Porphyry Silver Peak	Granite Porphyry Panamint	Granite Porphyry Silver Peak	Granite Porp Grapevine M tains
Proportions of phenocrysts and ground-mass	Phenocrysts= Ground-mass	Ground-mass > Phenocrysts	Ground-mass > Phenocrysts	Phenocrysts= Ground-m
Texture of ground-mass	Allotriomorphic with areas micropegmatitic	Allotriomorphic with areas micropegmatitic	Hypidiomorphic with micro-pegmatitic areas	Hypidiomorp
Quartz of ground-mass	Essential	Essential	Predominant	Predominant
Orthoclase of ground-mass	Essential	Microcline and orthoclase predominant	Essential	Essential
Plagioclase of ground-mass		Oligoclase	Present	Present
Other constituents of ground-mass		Biotite		
Quartz phenocrysts	Predominant	Predominant	Essential	Essential
Orthoclase phenocrysts	Essential	Essential	Essential	Predominant
Plagioclase phenocrysts	Present, Oligoclase-albite	Present	Present	Sparse
Microperthite	Orthoclase phenocrysts microperthitic		Orthoclase phenocrysts microperthitic	Orthoclase p crysts mic perthitic
Biotite phenocrysts	Rare	Rare	Rare	Rare
Hornblende phenocrysts				
Accessory minerals		Magnetite, Titanite, Apatite	Magnetite	Magnetite, Z Apatite, T
Micropegmatite of quartz and orthoclase	Ground-mass, also coronae around phenocrysts; also phenocrysts	Ground-mass	Ground-mass	

TABLE I

GRANULAR SILICEOUS ROCKS

Biotite-granite	Biotite-granite	Biotite-granite	Biotite-granite	Biotite-
Slate Ridge	Gold Mountain, West End	White Rock Spring, Pahute Mesa	Silver Peak	Gold M Ridge
Allotriomorphic	Hypidiomorphic	Hypidiomorphic with orthoclase poikilitic	Hypidiomorphic	Hypidio
Coarse	Fine	Coarse	Medium	Coarse
Essential	Predominant	Essential	Essential	Essentia
Predominant	Essential	Predominant	Predominant	Essentia
		Present	Present	Present
				Present
	Essential	Essential	Essential	Essentia
	x			
Essential	Essential	Not abundant	Essential	Essentia
	x	x		
	x	x		
x	x	x	x	
x	x	x	x	x

TABLE II

PORPHYRITIC ROCKS OF GRANULAR SILICEOUS SERIES

ry	Granite Porphyry	Granite Porphyry	Granite Porphyry	Granite Porphyry	
	Silver Peak	Grapevine Mountains	Kawich	Cactus Hills	
	Ground-mass > Phenocrysts	Phenocrysts = Ground-mass	Phenocrysts = Ground-mass	Phenocrysts > Ground-mass	
icro-	Hypidiomorphic with micro-pegmatitic areas	Hypidiomorphic	Hypidiomorphic	Hypidiomorphic	
	Predominant	Predominant	Essential	Essential	
or-	Essential	Essential	Essential	Essential	
omi-					
	Present	Present	Present	Present	
				Biotite	
	Essential	Essential	Essential	Subordinate	
	Essential	Predominant	Predominant	Predominant	
	Present	Sparse	Present	Sparse	
	Orthoclase phenocrysts microperthitic	Orthoclase phenocrysts microperthitic			
	Rare	Rare	Present	Essential	
ite,	Magnetite	Magnetite, Zircon, Apatite, Titanite	Magnetite, Zircon, Apatite	Magnetite, Zircon, Apatite	
	Ground-mass				

nite	Biotite-granite	Biotite-granite	Biotite-hornblende-granite	Quartz-monzonite
:	Gold Mountain Ridge	Lone Mountain	Belted Range	Panamint Mountains
rphic	Hypidiomorphic	Hypidiomorphic	Hypidiomorphic, porphyritic	Hypidiomorphic
	Coarse	Medium to coarse	Coarse	Medium
	Essential	Not abundant	Essential	Present
nt	Essential	Predominant	Predominant	Essential
		Present		Present
	Present			
	Present	Essential	Present	
	Essential	Present	Essential	Predominant
	Essential		Essential	Essential
			Essential	Essential
				Present
		x		x
		x	x	x
		x	x	
	x	x		x
		x		

nite Porphyry	Granite Porphyry	Quartz-monzonite Porphyry	Quartz-monzonite Porphyry
tus Hills	Gold Mountain Ridge	Gold Mountain Ridge	Silver Peak Range
nocrysts > round-mass idiomorphic	Phenocrysts > Ground-mass Hypidiomorphic	Phenocrysts > Ground-mass Allotriomorphic	Phenocrysts > Ground-mass Hypidiomorphic with poikilitic areas, quartz enclosing others
ntial	Essential	Predominant	Present
ntial	Predominant	Essential	Essential
ent te	Present Biotite essential	Present Biotite and Hornblende essential	Predominant
rdinate ominant	Essential Microperthite and microcline predominant	Orthoclase and microcline predominant	Essential
se		Essential	Predominant
	Phenocrysts		
ntial	Essential		Essential
			Present
etite, Zir-, Apatite	Magnetite, Apatite, Titanite	Magnetite, Titanite, Zircon, Magnetite	Magnetite, Apatite, Zircon, Allanite
	In ground-mass		

which were among the first to solidify from the magma and also in anhedra between the tabular feldspars, this titanite being among the last minerals to separate from the magma. In other phases of the pegmatite partial crystals of ferromagnesian minerals are inclosed in a coarse crystalline aggregate of feldspar. Microscopic examination shows that orthoclase and microperthite are so predominant over plagioclase in this rock that it has the composition of a syenite. A little quartz is present and the ferromagnesian minerals include augite, olivine, brown hornblende, and biotite. Augite in unusually large crystals and magnetite in grains also occur. In this rock there are associated the two minerals, quartz and olivine, which at one time were believed never to occur together.

Weathering.—Southwestern Nevada has an arid climate and consequently the granitoid rocks weather into a soil composed of fragments of the constituent minerals which are practically fresh. This mechanical disintegration, largely dependent upon stresses due to changes of temperature, is so rapid that broad basins of granitic soil extend up into the hills. Through these detrital embayments low domical outcrops of granite protrude and it is only in the highest peaks that exposures are conspicuous.

Age.—From the uniform amount of mashing which these rocks have suffered and from the similarity in the geological history of the various ranges, it is evident that all of these rocks are approximately of the same age. They intrude the Paleozoic rocks as batholiths, stocks, sheets, and dikes, where the contacts can be observed, and fragments of them are included in Tertiary lavas. The youngest Paleozoic rocks in the area are of Pennsylvanian age and these are intruded by granular igneous rocks in the Belted and Panamint ranges. The earliest lavas occur in the Stonewall Mountains and these rocks, which are of very late Cretaceous or early Eocene age,[1] contain fragments of granite. The granular rocks are, therefore, of post-Carboniferous and pre-Tertiary age. Spurr[2] found rocks of similar composition cutting Triassic strata in the Pilot and Excelsior

[1] Sydney H. Ball, *Bulletin 308 U. S. Geological Survey*, p. 33.

[2] J. E. Spurr, *Bulletin 208, U. S. Geological Survey*, pp. 103, 109.

(Nevada) ranges, and Louderback[1] states that granite intrudes Triassic rocks in the Humbolt (Nevada) range.

Later students of Nevada geology believe with King[2] that the mountain ranges of the western part of the state and the Sierra Nevada were formed simultaneously at the close of the Jurassic. The granite intrusion was probably a relatively late event in this period of deformation, an inference supported by the relatively unmashed condition of the granite. The erosion, prior to the outpouring of the earliest Tertiary lavas, of the thick covering of superincumbent rocks, which must have been present in order to produce the granular texture of the plutonic rocks also points to the post-Jurassic or very early Cretaceous age of the igneous rocks. Such an age determination is in harmony with that of the granodiorite of the Sierra Nevada. That mountain system and the ranges of western Nevada have had a closely parallel history.

While these granular siliceous rocks are thus believed to have been contemporaneous in a broad way, their consolidation unquestionably occurred at slightly different times. This is indicated not alone from the relation between the pegmatite of the quartz-monzonite and the soda-syenite of the Panamint Range, but also from the wide lithologic variety in the granular rocks of the Silver Peak Range (see column 7, Table I, and columns 1, 2, 6, and 7, Table II). There indeed the granular rocks may have solidified from wholly separate magmatic basins.

The conclusion as to the post-Jurassic age of these rocks is in accord with that of Spurr, for the granites of Silver Peak[3] and Goldfield,[4] Nevada, and that of Louderback[5] for similar rocks in the Humbolt Range, Nevada.

APLITE

The granitoid rocks of most of the areas are cut by narrow dikes of aplite, a fine-grained rock of white or pink color. In composition

[1] George D. Louderback, *Bulletin Geological Society of America*, Vol. XV, p. 318.

[2] Clarence King, *U. S. Geological Explor. 40th Parallel*, Vol. I, 1878, p. 759.

[3] J. E. Spurr, *Bi-monthly Bull. Amer. Inst. of Min. Engrs.*, 1905, No. 5, p. 955; also Professional Paper No. 55, *U. S. Geological Survey*, pp. 25, 26.

[4] J. E. Spurr, Bull. 260, *U. S. Geological Survey*, 1905, p. 133.

[5] G. D. Louderback, *Bull. Geol. Soc. of Amer.*, Vol. XV, 1904, p. 336.

the aplite and granitoid rocks differ in the relative proportions rather than in the kind of minerals present. The aplites are more siliceous than the older granitoid rocks, those of the granites usually having alaskitic affinities and those of the quartz-monzonite, granitic affinities. Upon weathering the aplites protrude from the surface of the granitoid rocks.

PEGMATITE

Pegmatite is usually associated with the granitoid rocks and is the only representative of the granular siliceous series at Bare Mountain, and is the predominant intrusive of the Bullfrog Hills. At most places it cuts the granitoid rocks with sharp contacts, and normally the intrusion of aplite intervened between that of granite and of pegmatite, although graduations from pegmatite to granite also occur. At one place in the Gold Mountain Ridge an aplite dike passes along its strike into a dike with narrow aplitic border and broad pegmatitic center.

The pegmatite usually occurs in well-defined dikes but throughout the more easterly of the two granite masses in the Pahute Mesa ellipsoidal masses of coarse quartz-feldspar-pegmatite are inclosed in the granite. The contact between the two rocks is at some places sharp, at others gradational. The ellipsoidal form and the absence of apparent channels from one mass to another in the plane of observation suggest that the pegmatite formed in place from the residual fluids of the granitic magma.

Chemically the pegmatites are more acid than their granitoid associates although in the Panamint Range the pegmatite of the quartz-monzonite has also undergone a considerable enrichment in soda. In texture the pegmatites are either coarse, irregular, granular aggregates or the intimate intergrowth commonly called graphic granite. The latter rock in the Gold Mountain Ridge is a transition phase between granite and coarsely granular pegmatite.

The pegmatites of southwestern Nevada contain but few rare minerals. Pyrite occurs as an original constituent of the pegmatite in the Belted Range and in the Bullfrog Hills. At the former locality it is reported to carry values in gold and silver and in 1905 was being prospected. The gradation from either a muscovite- or biotite-pegmatite to quartz veins is seen in most of the larger granite areas.

At the Bullfrog-George prospect in the Slate Ridge molybdenite, molybdite, and fluorite occur in a pegmatitic quartz vein. Molybdenite is present as metallic tablets and irregular scales of steel-gray color which lie between or are surrounded by the interlocking quartz crystals of the vein. It evidently solidified from the magmatic waters contemporaneously with the quartz. Its alteration product, a bright-yellow mineral in minute crystals and tufted aggregates, was determined by W. T. Schaller to be molybdite. Fluorite, which occurs in fractures in the quartz and also lines its vugs, is evidently somewhat younger than quartz and presumably was deposited by gases in the expiring stages of volcanism.

In the Bullfrog Hills there is some evidence of two separate intrusions of pegmatitic material. The older pegmatite is a feldspar-muscovite-quartz rock which is cut by a very siliceous pegmatite dike of almost pure quartz. It is probable then that from the residium of the granite magma a coarse-grained rock with the composition of a granite first separated and solidified and at a later period a more quartzose rock was deposited from the residual liquid in fractures in the older pegmatite.

QUARTZ-MONZONITE PORPHYRY

Dikes and sheets of quartz-monzonite porphyry, poor in ferromagnesian minerals, intrude Paleozoic rocks and granite of the Silver Peak Range and Slate Ridge. This rock near Lida is apparently cut by the diorite porphyry described below.

The monzonite porphyry is a dense white or greenish-white rock with abundant medium-sized phenocrysts, which however are subordinate in bulk to the ground-mass. They consist of whitish feldspars, some striated and others unstriated, silvery mica, and a few quartz crystals. The central portions of the dikes and sheets are more coarsely crystalline than the borders and in instances approach a granitoid texture.

Microscopic examination proves the medium-grained microgranitic ground mass to consist of orthoclase, microperthite, and anorthoclase grains, plagioclase laths, and a few quartz anhedra. In some thin sections the alkali feldspars poikilitically inclose the other minerals and in others quartz and orthoclase are in graphic intergrowth.

The phenocrysts of orthoclase and microperthite predominate over those of plagioclase (oligoclase and oligoclase-andesine). Altered biotite phenocrysts are constantly present while quartz crystals, much corroded, appear in some thin sections. Zircon and magnetite are accessory minerals.

This quartz-monzonite porphyry which evidently contains considerable soda, is younger than the granite which it cuts in the area four miles west of Alkali Springs and pebbles of it are included in the Siebert lake beds (Miocene).

DIORITE PORPHYRY AND DIORITE

Dikes of diorite porphyry and a few intrusive masses of diorite occur in the Silver Peak, Panamint, Grapevine, and Cactus ranges, the Gold Mountain and Slate ridges and the Bullfrog, Mount Jackson, and Lone Mountain hills. These rocks are hence confined to the western half of the area under consideration. In composition they range from acid diorite approaching granodiorite to a quartz-augite diorite of ophitic texture. Brown hornblende characterizes the more basic types and fragments of serpentine found in the Lone Mountain foothills may be altered forms of still more basic phases.

The diorite-porphyry and diorite are younger than the Paleozoic rocks and the igneous rocks already described, but nowhere were they observed cutting Tertiary lavas. Pebbles occur in the Siebert lake beds (Miocene) and the rock is probably of pre-Tertiary age.

The quartz-monzonite porphyry and the diorite porphyry and diorite, which are the youngest of the pre-Tertiary igneous rocks, occur only in comparatively small masses. They are probably complementary differentiation products of a magma residual from the solidification of the granular siliceous rocks.

THE VARIATIONS OF GLACIERS. XII[1]

HARRY FIELDING REID
Johns Hopkins University

The following is a brief summary of the report of the retiring president of the International Committee on Glaciers, which was presented to the International Congress of Geologists in Mexico in 1906.[2] The committee collects material regarding the variations of glaciers in all parts of the world; this material is collected in different ways in different countries. In Switzerland the Federal Foresters report on the changes in about 90 glaciers, and special work is being done in the study of the Rhone glacier under the auspices of the Helvetic Society of Natural Sciences. The German-Austrian Alpine Club encourages the observations of glaciers in the eastern Alps, the Italian Alpine Club and the Italian Geographical Society help in Italy, and there is a special committee in France which has lately received some help from the government in the observations of glacial variations. The Imperial Russian Geographical Society has done much in collecting and publishing the material regarding the little-known glaciers in the Russian Empire. The Norwegian Tourist Club in Norway, and the Swedish Tourist Club in Sweden have provided for the systematic study of glaciers in those countries, and lately the Swedish Geological Survey and the Reischtag have furnished pecuniary help. The glaciers of Greenland have been studied by exploratory expeditions sent out by the Danish government. Recent information regarding the glaciers of Iceland comes from the explorations of Dr. Thoroddsen; a topographic map now being made shows the positions of many glaciers. In Canada, also, the topographic maps are the most important contributions to glacial work being done by the government, but special studies of Canadian glaciers have been made independently by individuals. The same is true of the glaciers of New Zealand. In India the Geological Survey has undertaken to

[1] The earlier reports appeared in the *Journal of Geology*, Vols. III–XIII.

[2] The complete report will appear in the *Comptes rendus* of the Congress.

keep the record of the movements of some glaciers, but observations there in the past have been very desultory. No systematic work has been done by the government in the United States, although the maps made by the Geological Survey and the Coast and Geodetic Survey in glacial regions are of value in fixing the present positions of the glaciers. Reports regarding the Antarctic and Arctic regions must necessarily be irregular and must be obtained from exploratory expeditions to those regions.

Eleven annual reports have been published by the commission, the first ten in the "Archives des sciences physiques et naturelles," in Geneva. The eleventh report was published in the new *Zeitschrift für Gletscherkunde*, edited by Professor Eduard Brückner, of Vienna, and future reports will appear there. A glance at these reports will show that glaciers in all parts of the world are now retreating. The tendency to advance, which showed itself in the western Alps about 1885 and which slowly passed on to the eastern Alps has now practically disappeared. It did not extend to other glaciated regions.

Since the organization of the committee many theoretical and observational studies of glaciers have been made. It has been shown that when a glacier advances there is first an increase of thickness and of velocity in the higher parts of the glacier and that a wave of greater thickness and greater velocity travels down the glacier and causes an advance of the end; this wave originates in an increased accumulation in the reservoir, and in general the longer the glacier the longer time will be needed for the wave to reach the end. It has also been shown that the greatest thickness in the reservoir will occur some time after the maximum snowfall; so that the advance of the end may be many years after the period of maximum snowfall. If the glacier itself advances sooner than this theory would lead us to expect it must be due to diminished melting at the end, rather than to increased accumulation in the reservoir. The application of the idea of hydrodynamic lines of flow to the motion of glaciers has greatly increased our understanding of glacial phenomena, and it is to the further development and application of this idea that we must look for the increase of our knowledge of glaciers in the near future. The long-continued controversy as to the origin of the blue bands has been at

least partially solved. It has been quite clearly shown that the orderly systems of blue bands in the body of the dissipator are the modified strata; but it has not yet been shown that the bands which exist close to the bed and at the very end of the glacier belong to the above systems.[1]

The following is a summary of the Eleventh Annual Report of the International Committee on Glaciers:[2]

REPORT ON GLACIERS FOR 1905

Swiss Alps.—Of the ninety glaciers under observations in Switzerland, forty-nine were measured in 1905. The changes in five are uncertain; three glaciers are stationary and the other forty-one are in retreat. No glacier measured in 1905 showed any certain advance.[3]

Eastern Alps.—Observations were made in the summer of 1905 on sixty-one glaciers; forty-nine were in retreat, five were stationary, and seven had advanced somewhat, so that the general tendency to retreat still dominates. Of the seven advancing glaciers, five are in the mountains of the Oetzthal, where are situated also three of the stationary glaciers. The other two advancing glaciers are in the Goldberg group of the Hohen Tauern. The Grosselendkees, which is stationary, lies in the Ankogel group, the most easterly part of the Alps bearing glaciers. The Gliederferner in the Zillerthal Alps, which was advancing last year, is now in retreat.

[1] The following changes have been made in the committee. Professor Francesco Porro, formerly representing Italy on the commission, was elected to represent Argentina; Professor Olinto Marinelli succeeded him as representative of Italy; Mr. Charles Rabot, represents France, as the successor to Professor W. Kilian, who has retired; and Dr. E. von Drygalski was elected to report on the Antarctic regions; Professor Brückner was made ordinary member of the commission to represent Austria, succeeding Dr. A. Penck, who has removed to Berlin. Other corresponding members have been added as follows: Professor Dr. Hans Angerer, Mr. Charles Jacob, Mr. A. B. Harper, Major Hon. E. G. Bruce, Mr. W. S. Vaux, Jr., Mr. G. K. Gilbert, General Carlo Porro. Professor Penck and Professor Kilian were elected corresponding members on their withdrawal from the list of ordinary members. The committee lost by death two of its important members, Professor Eduard Richter of Graz, and Professor Israel Russell of Michigan. The following officers were elected to serve until the next meeting of the International Congress of Geologists: Honorary President, Prince Roland Bonaparte, of Paris; Active President, Professor Dr. Eduard Brückner, of Vienna; Secretary, M. Ernest Muret, of Lausanne.

[2] *Zeitschrift für Gletscherkunde*, Vol. I, pp. 161–81.

[3] *Report* of Professor Forel and M. Muret.

In opposition to this general tendency to retreat we notice that certain glaciers of the Oetzthal, which have been retreating pretty rapidly, are now retreating more slowly and some of them are even in a stationary condition.[1]

Italian Alps.—The Italian glaciers do not seem to show any marked variations, but the general tendency is to retreat.[2]

French Alps.—The glaciers in the Grandes Rousses of Dauphiné are in general retreat. A map of these glaciers on a scale of $\frac{1}{10000}$ is now being made. Measures of snowfall in the Savoy have shown a smaller amount in the winter of 1904–5, than in that of 1903–4. Special observations on the Mont Blanc chain have shown that the greatest snowfall occurs at an altitude in the neighborhood of 2,550 meters. The glaciers of Mont Blanc and the Maurienne show a slight retreat though there are indications of increased activity which later may bring on an advance. In the Vanoise and the upper valley of the Arc the glaciers continue to retreat, and some large snow fields have disappeared; others have been broken up by projecting ridges of rock.

Pyrenees.—The glaciers in these mountains are stationary or retreating. There have been very great changes since the middle of the last century; for instance, between 1855 and 1904, the glacier de l'Est has retreated 1,140 meters and the glacier de la Brèche, 1,230 meters. In the last two years there seems to be an increase of snowfall on these glaciers. The disappearance of some small glaciers in the French Alps and in the Pyrenees has been injurious to agriculture on account of the decreased quantity of water available for irrigation. This has led the Minister of Agriculture to offer pecuniary support to glacial observations.[3]

Sweden and Norway.—One glacier was observed in Sweden in 1905, the Mika, and it has retreated three to four meters. In Norway the changes have been mixed, some glaciers have retreated and some have advanced. The three glaciers observed in the Jostedal have advanced from 5 to 19 meters.[4]

[1] *Report* of Dr. H. Angerer.

[2] *Report* of Dr. F. Porro.

[3] *Report* of M. Charles Rabot.

[4] *Reports* of Dr. F. W. Svenonius and M. P. A. Oyen.

Russia.—In the mountain chain of Peter the Great, Boukhara, two glaciers show an advance since 1899, one of them as much as 64 meters. One in the Tian-Chan shows a retreat since 1892.

Caucasus.—Many glaciers have been visited and named; the Bartui has steadily been retreating; the retreat amounted to 30 meters in 1900–1, 12 meters in 1902–3, 13.5 meters in 1903–4. The glaciers of the Caucasus seem to be in general retreat.[1]

British Columbia and Alberta.—The Illecillewaet glacier continues to retreat, but much more slowly; it lost but 2 feet 6 inches between 1905 and 1906, though there has been a general shrinking in the volume of the ice. The tongue of the Asulkan glacier is slowly melting away under the moraine.[2]

South America.—A short description of the glaciers of Poto, just north of Lake Titicaca, Peru, has been given by Otto F. Pfordte.[3] The San Francisco glacier has high terminal moraines, but the present end has not varied much since the Spanish occupation, as shown by the ruins of houses at the foot of the cliff, where the glacier now ends. Old observations and traditions of the natives indicate that the snow-line is gradually receding in this part of the Andes, which accounts for the gradual lowering of the lakes. Mr. Bandelier,[4] referring to this same general neighborhood, states that the glaciers of the Bolivian Andes have been in slow retrocession for a number of years.

Central Africa.—The Mubuhu glacier on the eastern slopes of Ruwenzori is apparently in retreat. An old moraine overgrown with vegetation may be recognized some 500 meters in advance of the existing tongue of the glacier, and from the appearance of the rocks nearby it would seem that a slow retreat is now in progress (1905). Morainic lakes have been observed on the western slope below the limits of the present glaciers by Dr. Stuhlmann.[5]

[1] *Report* of Colonel J. de Schokalsky.

[2] *Report* of Messrs. G. and W. S. Vaux.

[3] "The Glaciers of Poto, Peru," *Proceedings of Eighth International Geographical Congress*, Washington, 1904, pp. 497–500.

[4] *Bulletin of the American Geographical Society*, 1905, Vol. XXXVII, p. 454; also *Scottish Geographical Magazine*, 1905, Vol. XXI, p. 586.

[5] *Report* of Mr. D. W. Freshfield.

REPORTS ON THE GLACIERS OF THE UNITED STATES FOR 1906[1]

The snow fall in the Rocky Mountains in the summer of 1905 was very heavy and perhaps for that reason the Hallet Glacier shows a slight advance (*Mills*). But there has been a slight retreat at the north end of Arapahoe Glacier, which is not far from the Hallet (*Henderson*). The glaciers in the Montana Rockies are either stationary or slightly retreating (*Chaney*). A small glacier reported in Bighorn Mountains of Wyoming has apparently disappeared (*Salisbury*).

On the north side of Mt. Hood, Washington, Eliot Glacier is diminishing very markedly. The ice is growing much thinner at the end and a more rapid retreat will probably appear before long. Some of the snowfields are greatly altered and the ascent of the mountain has been rendered much more difficult than heretofore (*Mrs. Langille*). On the south side of Mt. Hood, the White Glacier has diminished in thickness but does not seem to have receded materially (*Montgomery*). Glacier Peak, in Washington, was climbed last summer by Mr. C. E. Rusk. He found that the glaciers showed signs of retreat but less than in other places in Washington; these glaciers carry comparatively little débris. Mount Baker was visited last summer by the Mazama Club, of Portland, Oregon; their magazine contained many excellent pictures of the glaciers and a sketch map of the mountain, showing a number of distinct glaciers, but no information is given as to the recent changes. When this mountain was visited in 1903 by Messrs. Rusk and Campbell there was a small, well-marked crater at the summit, about 50 feet in diameter, from which considerable volumes of black smoke were rolling away. In 1906 this vent was completely filled with snow and no evidence of its existence appeared except a slight depression in the surface of the snow (*Rusk*).

Last summer Messrs. F. E. and C. W. Wright visited Glacier Bay and repeated the survey which was made in that region in 1892. They found very remarkable changes in all the glaciers. The only definite information we have had of any of these glaciers since 1899,

[1] A synopsis of this report will appear in the *Twelfth Annual Report* of the International Committee. The report of the glaciers of the United States for 1905 was given in this *Journal*, Vol. XIV, pp. 406–10.

until the Messrs. Wright's visit, was due to a trip to Muir Glacier by Messrs. Andrews and Case, in May, 1903, and they reported a very considerable recession in that glacier.[1] The report of the Messrs. Wright will not be published before next winter but they have very kindly prepared an abstract of the glacial changes which they observed as follows;[2]

On comparing our map with your map of 1892, the following changes are most apparent: Beginning with Muir Glacier and its tributaries the ice front has receded a maximum distance of about 33,000 feet; Dirt Glacier is no longer tidal; White and Adams Glaciers are supplying very little ice to the general ice field; Morse Glacier terminus is about one mile from tide water; the crest of the stagnant ice mass between Girdled Glacier and Muir Inlet has melted down about 200 feet since the time of your measurements; Girdled Glacier and Berg Lake, however, have not changed materially in aspect. The length of the total ice front of Muir Glacier is now over 40,000 feet instead of 9,000 feet in 1892. The present ice front passes at its northern extremity at about the position of your 1,000 feet contour on the ice of 1892. This remarkable decrease in elevation is undoubtedly due not only to melting down but also to breaking down of the exposed ice masses. The ascent of the ice mass at this point is decidedly steep and the ice fairly cascades into the water. The present height of the ice fronts of all the tide water glaciers is about the same as noted by you in 1892 (150′–250′), and is a noteworthy fact in connection with these glaciers. Muir Inlet is at present choked by the ice pack which promises to remain congested so long as its source of supply is so active. A considerable portion of the present front of Muir Glacier is in very shallow water and in a few years should decrease in size very materially unless new avenues and inlets for tidal currents are exposed by the receding ice. Dying Glacier is still creeping back and wasting away.

Carroll Glacier has not changed much in aspect during the last 14 years; its terminal cliff has receded about 2,000 feet and at present, apparently, is continuing to do so. It is discharging icebergs very slowly and Queen Inlet is nearly free of ice.

Rendu Glacier has also changed but little and its front is about 2,000 feet back of its position in 1892. This Inlet also is not impeded by any amount of ice. The small glacier cascading from the west near its terminus appears to have changed still less.

In Reid Inlet the changes have been very great and things are still moving at a

[1] C. L. Andrews, "Muir Glacier," *National Geographical Magazine*, 1903, Vol. XIV, pp. 441–45, and this *Journal*, 1904, Vol. XII, p. 258. The positions of the glaciers in 1899 are described by G. K. Gilbert in the *Harriman Alaska Expedition*, Vol. III.

[2] A map of this region accompanies an article on "Glacier Bay and Its Glaciers," in the *Sixteenth Annual Report of the United States Geological Survey*, 1894–95.

rapid rate there. The inlet was congested with the ice pack last summer and on the south side near the large island the ice jam was completely frozen over and moved as one mass back and forth with the tides.

Grand Pacific Glacier has receded and left the large granite island surrounded by water. It has receded nearly 20,000 feet; but judging from the amount of ice it is now discharging and the shape of its valley it will not recede so rapidly in the next few years, other conditions remaining the same.

Johns Hopkins Glacier has receded about 11,000 feet and is still sending off icebergs at a rapid rate. The unnamed glacier directly east has become detached from it and is much like Reid Glacier in character and appearance.

Reid Glacier has receded perhaps 5,000 feet and still preserves its original aspect as indicated on your map.

The small dying glacier between Reid and Hugh Miller Glaciers has practically disappeared. At least no ice was visible in the rock and moraine débris.

Hugh Miller Glacier no longer reaches tide water in Reid Inlet and at low tide is nearly a mile back from it. The tide flats are long and with only a slight grade. In Hugh Miller Inlet this glacier was exposed to tide water only in the southwestern bay, where its front is intercepted in its central part by a large promontory of light colored granite. Eight thousand feet is approximately its amount of recession since 1892. Charpentier Glacier also receded about 9,000 feet and promises to continue its recession rapidly, especially along its southern front as its valley is opening out and allowing a greater exposure of ice front to the action of tide water.

The small stagnant glacier east of Charpentier is simply melting away and will probably disappear in ten or twenty years.

Favorite Glacier is still receding. Wood Glacier is no longer tidal and only a small part of Geikie Glacier ice front is exposed to salt water. Geikie Glacier has receded about 5,000 feet during the past 14 years.

On the whole, recession has been the rule for the glaciers of Glacier Bay. Those glaciers have receded most whose ice fronts have, on recession, increased appreciably in length. In the past 14 years the combined ice front of all the glaciers exposed to tide water has increased from 17,000 feet to over 40,000 feet and the amount of recession has in that time alone equalled that of the previous 20 years.

To the west of Glacier Bay, Brady Glacier in Taylor Bay has receded considerably. In Lituya Bay, the glacier at the northwestern end of the bay has advanced about one-half mile since 1894; the central and southeastern glaciers have apparently remained unchanged although the latter may have advanced slightly.

The two glaciers at the ends of the bay were reported in 1894 to be about three kilometers in advance of their positions of 1786. It is curious that the glaciers of Lituya Bay should be advancing, while those of Glacier Bay, about fifty kilometers to the east, are retreating so markedly.

It will be remembered that when Professor Tarr visited the region about Yakutat Bay in 1905 he found that the glaciers showed a general tendency to retreat, though the changes were not very great for tide-water glaciers. When he visited the region again in 1906, remarkable changes had taken place. The Marvine Glacier, to the west of Yakutat Bay, supplies the ice for the eastern part of the Malaspina Glacier; though all previous explorers had found it comparatively smooth and easily traversed, it had become greatly broken and crevassed. The glaciers next to the east, the Hayden and the Lucia, showed no such changes, whereas the Atrevida, next to the Lucia, exhibited changes similar to those of the Marvine. The Seward Glacier, farther west, which is the largest glacier supplying the Malaspina, seemed to be more crevassed than it was when crossed by the Duke of the Abruzzi in 1900, but was not broken and torn like the Atrevida and the Marvine. The part of the Malaspina Glacier which derives its ice from the Marvine, was full of crevasses for a distance of twelve to fifteen miles. The southern border of the Malaspina Glacier, which was formerly stagnant ice completely covered with moraine and heavy vegetation, has been so broken up that great blocks of ice are falling from the end, the moraine is sliding off, and the trees have been overturned. The Turner Glacier, which enters the western side of Disenchantment Bay showed no decided changes, whereas, the Haenke, a small glacier lying immediately north of the Turner, was advancing into the water; it had joined the end of the Turner Glacier and had thus lengthened the ice front by about a mile. The great Hubbard Glacier, which comes in from the north, showed no change, whereas the Orange Glacier immediately to the southeast, which in 1905 was smooth and easily traveled, was so broken in 1906 that even the lower part could not be traversed, and the region of stagnant ice covered by moraine had been transformed into clear ice, crevassed and pinnacled. That these remarkable changes had taken place between the summers of 1905 and 1906 is clearly shown by the observations and photographs of Professor Tarr; and that the advance, at least at the end of the Malaspina Glacier, was still in progress, was shown by the fact that the overturned trees had put forth their leaves in the early summer before being uprooted. The fact that certain glaciers, presenting, so far as

could be observed, no special characteristics, had experienced such changes, whereas adjoining ones had not, makes it evident that these changes were not due merely to general climatic conditions, but to some special cause. Professor Tarr suggests that this cause was the severe earthquakes which occurred in this region in September, 1899, and which brought about marked changes of level, in some places amounting to 40 feet.[1] Professor Tarr thinks that these earthquakes shook down enormous quantities of snow and ice from the surrounding mountains and thus added so large a supply to the reservoirs or to the upper parts of the dissipators of some of the glaciers as to cause a sudden and great increase in the velocity, resulting in a strong thrust, which produced abundant crevasses. Some glaciers, on account of the forms of the surrounding mountains, may not have received such great additions to their masses; and others, on account of greater length, may require several years before the change is shown in their lower portions. Professor Tarr's explanation seems entirely satisfactory and is supported by the observation of Mr. A. H. Brooks, who in September, 1899, was on the eastern side of the St. Elias chain and reports that he heard unusually large avalanches falling from the mountains. Examples are known of glaciers which have advanced when neighboring glaciers were retreating, due to the protection of their surfaces by avalanches of snow or by land slides; but the present case seems to be far more remarkable than any heretofore reported and it is greatly to be hoped that observations will be continued and the future changes recorded.[2] At present we only have sketch maps of these regions, but at some future time, when better maps are made we may be able to show more clearly the causes of the different behavior of the various glaciers.

[1] Ralph S. Tarr and Lawrence Martin, "Recent Changes of Level in the Yakutat Bay Region, Alaska," *Bulletin of the Geological Society of America*, 1906, Vol. XVII, pp. 29–64.

[2] Professor W. H. Sherzer has described some moraines in the Canadian Rockies, made up entirely of large blocks of rock. He thinks that this material may have been shaken down upon the glaciers by earthquakes. See "Glacial Studies in the Canadian Rockies and Selkirks," *Smithsonian Miscellaneous Collections*, 1905, Vol. XLVII, Part. 4, pp. 494–96.

FLAXMAN ISLAND, A GLACIAL REMNANT

ERNEST DE KOVEN LEFFINGWELL
Flaxman Island, Alaska.

Flaxman Island is located close to the north shore of Alaska, approximately in Lat. 70°, Long. 146°, and a hundred miles west of the international boundary. It is one of the innumerable small islands that fringe the coast between Point Barrow and Demarcation Point. Failing to reach their goal in Banks Land, this island was chosen as the winter quarters of the Anglo-American Polar Expedition, commanded by Capt. Ejnar Mikklesen, and the writer.

A couple of miles to the south lies the mainland, a low tundra plain extending some twenty miles back to the mountains. Both the mountains and the coastal plain are characteristic features of the northern part of Alaska. From Cape Lisburn on the west coast a chain of mountains runs eastward into Canada, separated from the ocean by a plain of greater or less width. At Point Barrow the plain is over a hundred miles wide, but it narrows to the eastward until at Demarcation Point the mountains come within a few miles of the coast.

Opposite Flaxman Island the nearer mountains have an elevation of between three and four thousand feet, but higher peaks can be seen beyond. The map[1] gives seven thousand feet along the Arctic-Yukon divide, but prospectors estimate it higher. From this chain several rivers make their way across the tundra to the Arctic Ocean. The Coville is probably the largest, but the Kugura is reported to be about 280 miles long.[2]

The coastal plain is covered with moss and grass, and with its ponds, lakes, and swamps forms a characteristic tundra. Near the ocean it usually ends in a low mud cliff which seldom reaches a height of thirty feet. Small bays and lagoons, behind sand spits and bar-

[1] Map of Alaska, *U. S. Geological Survey*, 1904.

[2] Schrader, F. C., Professional Paper, No. 20, p. 31, *U. S. Geological Survey*.

rier reefs, fringe the shore, while at a distance of a few miles occurs a nearly continuous chain of islands. With two exceptions known to the writer (Flaxman and Barter Islands, which are tundra) these are exposed portions of a wave-built barrier reef. Inside is a long shallow lagoon along which it is possible for light-draught vessels to make their way for miles, protected from the ice pack.

Flaxman Island is about three miles long and half a mile wide, running nearly parallel to the mainland. Its surface is a tundra plain about twenty feet above the sea. Ponds are scattered over the

FIG. 1.—A portion of the coast of Flaxman Island.

surface, and large crystalline boulders are frequently met with lying half buried in the soil. Immediately over the beach the plain ends in a steep mud cliff which is broken by frequent gullies. The beach itself is studded with boulders which are seen in all stages of being, weathered out of the cliff as it recedes under the action of the elements.

Where the cliff affords a good exposure, ice is nearly always seen immediately underlying the soil. Usually only a few feet are found, but on the northeast shore there are places showing at least twenty feet. Nowhere is the base of the ice exposed, so no estimate of its thickness can be made. The surface waters have often melted little

canyons into the ice by means of which its presence can be traced thirty to forty feet back from the face of the cliff. About thirty yards back, near the winter quarters, the writer found nearly pure fresh water ice, after digging through one foot of soil, and the same amount of frozen clay. It is the intention of the expedition to obtain their winter's supply of fresh water by sinking a shaft down into this ice, at the same time learning something further as to its thickness and constitution.

Its frequent exposure along the cliffs and its presence some distance inland, points to the presumption that the ground-ice formation underlies the whole island. As is the rule in arctic regions, the ground remains permanently frozen to an unknown depth. Only the upper foot or two thaw out during the short summer. At Point Barrow, Lieutenant Ray dug over thirty-five feet down without penetrating the frozen layer. At the bottom a temperature of 12° F. was held for months. This being the case, it is easily understood how a body of ice, once covered with a few feet of soil, would endure a very long time in the Arctic regions. Practically the only way such an island as this can be destroyed, is by wave-cutting at the sides and the consequent direct exposure of the ice to the sun. This is taking place very rapidly on the seaward side, as freshly fallen blocks of peat and ice show.

Good exposures show a mass of clean ice with an occasional discolored band running haphazard across it. There is no apparent stratification, and the ice is very clean as a whole. When the ice is examined closely it is seen to be full of minute air bubbles and to be coarsely granulated; which shows that it could not have been formed by the freezing of a body of standing water. It must be either glacier ice or snow that has become coarsely granulated by great age.

A single glance at the boulders scattered over the surface and weathered out along the beach is at once suggestive of glacial drift. Most of them have the characteristic outlines of glacial boulders, but many are angular from the shattering action of the intense frost. Their lithological heterogeneity is very striking. Among the crystallines it seems as if the whole gamut were run, but the sedimentaries seem to be confined to quartzites and limestones. The quartzites are the most conspicuous—pink, red, and purple; often banded, cross-

bedded, or conglomeratic. Next come dark crystallines of the gabbro type, then pink granites, then buff limestones. A few moments' search revealed abundant striae, not only on the limestones but on the crystallines as well. A quarter of an hour's walk along the beach showed scores of boulders so definitely striated that any one of them would settle the question of their glacial origin.

It next remains to inquire into the age of the ice. A careful search was made around the whole border of the island, but the base of the ice was nowhere visible. It cannot be denied, then, that some

FIG. 2.—Another part of the coast.

of the boulders might have come from beneath, but many, and probably most, of them came from the few feet of till that lies on top of the ice. Several were seen with ice immediately below them in the face of the cliff. Consequently there seems no escape from the conclusion that the ice is of equal or greater age than the glacial till that lies above it.

Two boulders, approximately ten and fifteen inches in diameter, were found imbedded in the ice itself. The former lay in the lower portion of a few feet of ice exposed in the cliff; the latter, thirty feet back from the face of the cliff, in the vertical wall of clear ice that

formed one side of a channel melted to a depth of five feet by the surface waters. We have seen that the ground ice probably underlies the whole island, that it is covered with glacial drift, and contains boulders imbedded within it; so the conclusion is forced upon us that our island is simply a portion of a glacier that has been kept from melting by a thin coating of drift upon its surface.

Naturally the mountains on the mainland to the south are to be looked to for the source of the glacier by which Flaxman Island was formed. As we have said, a chain of mountains about three thousand

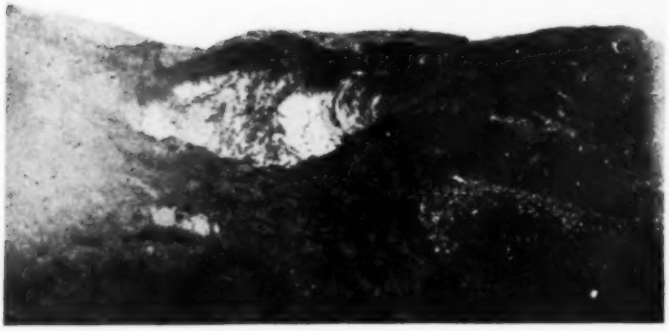

FIG. 3.—A characteristic exposure

feet high runs parallel to the coast at a distance of some thirty miles inland. Through this the Kugura River breaks after heading among the higher peaks beyond. As seen from a distance, the nearer range does not seem to have suffered intense glaciation. It certainly was not covered by an ice cap; but small glaciers may have occupied the valleys on the north side. The presence of a piedmont glacier is not improbable. The deep cut of the Kugura, however, in its rounded outline has a heavily glaciated look, and it is here that we must look for the source of the ice that forms our island.

In his report on the Koyukuk, John, Anaktuvuk, and Coville

Rivers, Schrader[1] deals at some length with the glaciation of the region.

> The glacial phenomena that have been described tend to show that, although the Endicotte Mountains do not on the whole seem to have been overridden by a moving ice cap, they were doubtless, especially in the northern part, largely occupied by an ice cap or perennial nevé constituting a breeding-ground for glaciers.

The mountains he traversed reached an elevation of between five and six thousand feet and he found no living glaciers, yet a heavy body of ice pushed northward along the valley of the Coville. Around the

FIG. 4.—A striated boulder on the island.

headwaters of the Kugura elevations of over seven thousand occur, and valley glaciers[2] of considerable size are reported to exist. Taking these things into consideration, it is to be expected that the basin of the Kugura would be occupied by a glacier of sufficient magnitude to push thirty miles beyond the mountains and reach the sea.

The presence of ground ice a few feet below the surface of the tundra is a characteristic feature of the Arctic coastal plain. Dall[3] is of the opinion that it is a widespread phenomenon, but Schrader[4]

[1] *Op. cit.*, p. 91. [2] Schrader, *op. cit.*, p. 30.

[3] W. H. Dall, "Correlation Papers," *Bull. U. S. Geological Survey*, No. 84, p. 92.

[4] *Op. cit.*, p. 92.

doubts its general occurrence. However widespread it may ultimately prove to be, it is certainly an interesting feature. Schrader's theory[1] is that the ground ice is the result of "frozen bays, lagoons, lakelets, or perhaps other coastal bodies of ponded water now raised into low anticlines and cut back by wave action." The localities visited by him were Capes Simpson and Halkett, between Point Barrow and the Coville River. Here the ice evidently was not glacial, for boulders are not known to exist on the beach west of Flaxman Island. An inquiry into the presence of air bubbles or granulation would soon settle the question as to whether the ground ice in that region could be accounted for by the freezing of bodies of standing water.

The writer believes that he has shown that the ground ice at Flaxman Island is of glacial origin. Its occurrence there is very similar to that of the same formation elsewhere, in that it closely underlies the tundra along the mud cliffs which are such a common feature on the northern shore of Alaska. If future investigation shows that the ice could have resulted from the freezing of bodies of standing water, the explanation given by Schrader seems the most probable one. But if it is granulated, the writer is of the opinion that its history will be found to be connected with that of the region during the glacial period. The following hypothesis is suggested:

At present the coastal plain is free from snow scarcely three months in the year. During the glacial period the snow did not entirely disappear during the short summer, but accumulated in favorable localities. As the climate grew warmer, silt was brought down by the mountain streams and distributed over the ice by the wind. Moss and grass quickly took root and increased the thickness by the formation of peat. Wherever this covering reached a sufficient depth the ice was prevented from melting and has remained until the present day. Where the thickness was insufficient, the ice melted leaving the depressions which are now occupied by the ponds and lakes which are such a characteristic feature of the tundra.[2]

The temperature of the plain adjacent to the Arctic Ocean is kept in the neighborhood of freezing by the presence of the ice-laden

[1] *Op. cit.*, p. 96.

[2] Schrader, *op. cit.*, p. 46.

waters. Inland the temperature is much higher. Schrader[1] reports the water of the Coville as being 52° F. near where it leaves the mountains. Consequently not only would the accumulation of snow be greater near the coast, but the subsequent melting less. The ground ice should therefore be confined to a narrow belt along the coast.

October 15, 1906

[1] *Op. cit.*, p. 129.

A NOTE ON THE GEOLOGY OF THE COSO RANGE, INYO COUNTY, CAL.

JOHN A. REID
Stockton, Cal.

The completion of the geological history of the Sierra Nevada and associated ranges appears to rest, for practical reasons, upon the determination, at different times and in different places, of the necessary facts. It is with this in mind that the writer presents the following data, ascertained on a recent short business trip. It is hoped that others may be fortunate enough to be able to dig more deeply into the rocks, both in the locality described and elsewhere in the adjacent regions.

The Coso Range lies between the Sierra Nevada on the west and the Darwin or Argus Range on the east, separated from each by a long narrow valley. At the north end the Coso Range forms the south boundary of Owens Valley, and extends thence southerly along its main axis for about forty-five miles. The greatest width at the north is twenty miles (see map, Fig. 1). A number of general statements have been made regarding this peculiar range, with but little in detail.

From whatever point of view seen, the Coso Range is strikingly different in appearance from the surrounding mountains. Fig. 2 shows the Range looking south from Keeler. The typical appearance is here well outlined. The flat, nearly horizontal, sky line, with, in general, gentle slopes to the bordering valleys, give an air of maturity not found in the precipitous fault scarps of the Basin Ranges. One comparatively small scarp is seen in the eastern part of the range, facing northeast, and its supplementary scarp occurs in the western portion. The form of the whole is that of a very flat elliptical dome, with its longer axis lying north and south. The periphery of this dome grades into the surrounding valley alluvium. The northern and western flanks are largely covered with basalt flows; the eastern

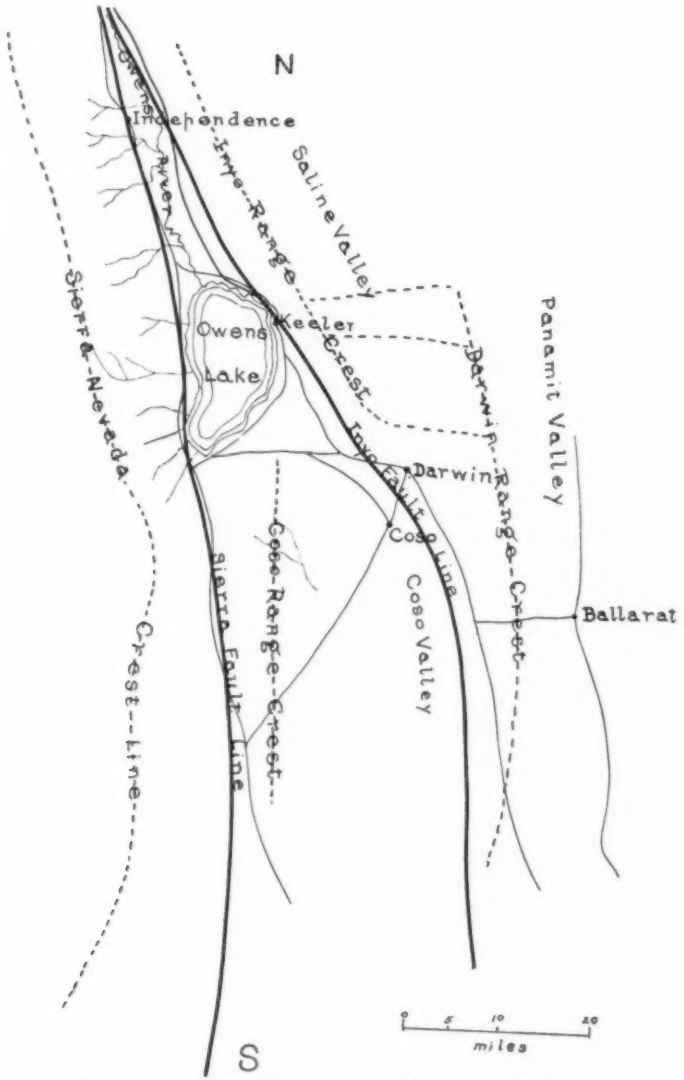

FIG. 1.—Sketch map of region surrounding the Coso Range.

side, facing Coso Valley, is free from these late volcanics. From Darwin, elevation 4,746 feet, on traveling westward, there comes first a long alluvial slope of about five miles, with small granite knobs and low hills rising slightly above the surface. Fig. 3 gives a view south of Darwin, showing a long eastern spur of the Coso Mountains which extends sufficiently far to show the effects of the faulting along the Coso Valley line. The contrast between the low granite hills and the fault topography of the Darwin Range is very evident.

FIG. 2.—View of Coso Range looking south from Keeler. Shows east-west profile of range and east fault scarp. The low basalt ridge connecting the Coso and Inyo ranges is seen at left.

From the upper edge of the alluvial apron, an elevation of 5,200 feet, the granite rises gradually westward for 2 miles to the foot of the fault scarp shown in Fig. 2, at an elevation of approximately 5,500 feet. Above this base the range rises about 1,900 feet. The fault scarp itself is less than 1,000 feet, though originally it may have been much more. From the east fault the east-west profile of the range is well shown in Fig. 2, with the gradual merging of the dome into the western valley. The north-south profile, see Fig. 4, is similar, with Coso Peak as the center and highest point. The present

height and character of Coso Peak are due in part to faulting; probably it is also near the original center of the granitic dome.

The granitic slopes descend on the east and disappear beneath the alluvial apron. But there are several important facts to be noted concerning this. In the slopes just west of Darwin the alluvium is deeply trenched by present wet weather streams. This trenching varies from a few feet in Coso Valley (see Fig. 3) to 75 feet or more in the low hills. The same dissection of alluvial aprons and fans is

FIG. 3.—View south over Darwin, showing low Coso hills at right, and fault topography of Darwin Range to left. Wet-weather stream wash in middle distance over Darwin.

found along the east base of the Sierra Nevada as far north at least as Carson City, Nev., and indicates a widespread climatic change. The conditions of large, heavily loaded torrential streams have been replaced by those of small, lightly loaded wet-weather ones.

In the Coso hills the stream gullies, locally termed washes, have exposed the nature of the material lying upon the granite. The surface layer is a coarse, angular, granitic sand, showing no traces of water action. That lying lower, on the crystalline base, varying in thickness from ten to thirty feet where seen, is stratified, and dips

very gently to the east. These beds are water-laid granitic sands of finer grain than the unsorted stuff above. They average six inches in thickness.

These water-laid strata might excite little more than passing notice were it not for the fact that they belong to an extensive formation. In traveling to Darwin from Keeler the road traverses the beds of the present lake to the north edge of the basalt flows shown in Fig. 4. The older Owens Lake cuts a small cliff in the volcanic about 150

FIG. 4.—View of Coso Range looking southwest from high end of Inyo Range. Basalt ridge in right center rests on lake beds at south edge, and is notched by older Owens Lake on north. Basalt shows much faulting. The white area south of basalt ridge is composed of lake beds with some recent alluvium. Coso Peak in left center, snow capped. Sierra Nevada—on extreme right.

feet higher than the present water level. Three well-formed beaches are preserved, with a number of smaller imperfect ones. Southward the basalt is found lying upon rather coarse sands stratified poorly at the top and well bedded below. These beds are granitic where examined, with traces of volcanic ash. Some finely stratified fine-grained beds occur in the lower part of the formation near the center of the valley, which seem to contain considerable ashy material; also some few small pebbles of schist and finer detritus of like nature

are found, but no such rocks were noted in place. The greatest thickness of the beds is about two hundred feet, with the base not exposed. In areal extent they persist from the basalt ridge on the north (see Fig. 4) to a low easterly spur of granite about eight miles north of Darwin. From this ridge southward the beds were not seen except in the exposures west of Darwin. The highest elevation is on the low granite spur, 60 feet above the bench mark of the U. S. Geological Survey marked elevation 5,101 feet. Here the section

FIG. 5.—Basalt-covered low south end of Inyo Range, looking southeast from Keeler. Shows the intense faulting of the late basalt flows resting on the old sedimentaries and Tertiary lake beds low down.

is small but complete. On the crystalline base, nearly horizontal, is roughly one hundred feet of well-stratified granitic sandstone, with one foot of reddened material at the top, overlaid by basalt. There is a slight northerly dip. Just south of the point of greatest elevation the stratified rock lies horizontal at a lower elevation.

In the basalt-covered portion of the low south end of the Inyo Range similar arenaceous beds are burned by volcanic flows (see Fig. 5). East of Keeler, above the deposits of the older Owens Lake, occurs a large amount of sand, which may, and probably does, repre-

sent a northerly continuation of the same beds. In general these beds dip slightly to the north; locally they are either gently folded, or broken and faulted near the basalt flows. The lowest elevation of their exposures is 3,760 feet, south of Keeler; the highest is 5,160 feet, nearer Darwin. This gives a vertical range of at least 1,400 feet and a height above the present lake of 1,560 feet. Lake beds are noted by Fairbanks,[1] occurring on the west flank of the Coso Range, which correspond in elevation with those on the east. These lake deposits probably extended northward and joined with those of Wancobi Lake of Walcott.[2] Spurr[3] has given a brief résumé of the existing knowledge of these, and concludes that no local faulting has been the cause of the elevation of the Wancobi beds. In the Coso strata many small faults have occurred, but it is very doubtful if their present position is due in the main to differential motion of the underlying rocks. If this be so, it is entirely probable that one large lake existed over this region, as Spurr[3] concludes, which was drained by tilting north and south from a point in the vicinity of Mono Lake. At this latter locality the beds are at elevation 7,100 feet; at Wancobi embayment 7,000 feet; and near Darwin at 5,200 feet. These figures would indicate a differential tilting, which combined with the fact of much faulting of the basalt overlying the lake beds southeast of Keeler (see Fig. 5), makes it very probable that local elevation in the Inyo Range has caused a part of the present elevation of the lacustrine formation.

A further point noted in the stream gullies west of Darwin is that the granite, though showing no faults of size, is intensely fractured as if squeezed between powerful jaws. The complexity of these small movements is well shown by the quartz veins, which are most intricately displaced in small blocks. The prevailing mode of this displacement consists of a series of northeast-southwest faults dipping northerly, along which the north walls have moved westward. The best-developed joints strike N. 40 W. with a dip of 85° northeast. The rocks are deeply weathered, with the surface covered by rounded boulders of disintegration.

[1] *American Geologist*, Vol. XVII, p. 69.

[2] *Journal of Geology*, Vol. V, pp. 340–48.

[3] *Bulletin 208*, U. S. Geological Survey, pp. 209, 210.

Of the rocks themselves no detailed petrographic investigation seems to have been made. The various writers have described them as granitic, with basalt flows north and west. The granite of the dome has the characteristics of the intrusive granodiorite of the Sierra Nevada, and ranges from a basic hornblende-biotite granite to a diorite. Traces of an older basic diorite are included in the normal facies. A few dark-colored basic dikes and a great number of pegmatite dikes also occur. Dikes of diorite-porphyrite are found, striking in general north and south. These are frequently andesitic in character. The basalt flows are agglomeratic at the base, grading upward to massive, often vesicular, at the top. Some of the earlier mud flows picked up considerable sandy material from the lake beds. The quartz veins are small and in two series, of different ages and characteristics in the localities visited. The older veins strike northwest and southeast and bear evidence of having been formed at great depths, the present veins being but the roots of the original ones. The gangue is quartz, with strong alteration of the granite walls. This alteration is shown by the development of large plates of biotite and the recrystallization of the constituents of the grano-diorite for a short distance from the vein. The ores are pyrite and chalcopyrite, carrying some gold. The later quartz veins strike northeast and southwest. The granite near the veins is metasomatically replaced by silica at times. The ores are pyrite, chalcopyrite, sphalerite, galena, sulphantimonides of silver and lead, and finely divided free gold rich in silver. These veins are connected genetically with the intrusions of the diorite-porphyrite, as seen in exposures studied in the Inyo Range to the north.

The Coso Range is peculiar in that its line of evolution did not wholly follow those of the surrounding ranges. The first uplift was simultaneous with the intrusion of the Sierra Nevada batholith, after which it was probably a range of great height and geographic importance. It must at that time have formed a southeast extension of the older Sierra Nevada, though probably as a distinct range underlaid by an intrusive granitic dome. The overlying sedimentaries were removed almost entirely by erosion before Tertiary faulting broke a long stable condition of the crust and formed lake basins along the east flank of the Sierra. The lines of this faulting were such

that the Coso Range became a very distinct unit, one main fault going to the west and forming the east wall of the Sierra, another passing to the east and forming the west wall of the Darwin Range (see Fig. 1). The large lake in which the Wancobi and Coso beds were deposited was formed at this time, and granitic detritus deposited from the Coso Mountains in the arm north of Darwin. The occurrence of the few fragments of schist indicates that the last remains of the older rocks in the body of the range were removed just previous to, and in part coincident with, the draining of the lake. The only locality where the older rocks yet remain is in an east-west ridge about eight miles north of Darwin and just east of the low granite spur noted above as marking a south limit of the lake beds. On this east-west ridge of older rocks is exposed a magnificent section about a mile thick, the strata dipping uniformly east at about 45°. No time could be given to an examination of these rocks. The older lake basin was eventually drained by further movements along the fault planes, and basalt eruptions covered the west and north flanks of the Coso Mountains, the south end of the Inyo Range, and a large area of the lake beds south of Keeler. As some of the basalt lies upon unstratified sands which are above the lake strata, the lake must have been partly drained previous to the initiation of the volcanic flows.

Still later faulting along the old lines produced further elevation of the Inyo Range and differential movements of the lake beds along this sierra. Through it all the Coso Range was faulted only by small displacements, caused by its position between the two great converging faults to east and west. Thus these comparatively insignificant mountains stand as a monument of the older geologic time when the western cordillera was composed of low mature ranges not characterized by the excessive and great faulting seen today.

A NATURAL BRIDGE DUE TO STREAM MEANDERING

V. H. BARNETT

Natural bridges were originally referred to the agency of caverns, as explained in Scott's *Geology*[1] and most of the less recent works. Scott gives the Natural Bridge of Virginia as an example of this method of formation, and it was not until 1893, when Walcott[2] described the bridge, that it was considered as having been formed in another way. Cleland[3] has reviewed several methods of origin in an article in the *American Journal of Science*, but so far as the writer knows none have ever been described as being due to stream meandering.

The bridge here described is located south of the White River below the mouth of Porcupine Creek, in South Dakota, and was visited by the writer in 1905, while working as field assistant to Professor E. S. Riggs, of the Field Columbian Museum. It is formed of White River beds. The opening of the archway is about 12 feet high by 8 feet wide, and the thickness of the arch is something like 10 feet in a vertical direction by 7 feet in a horizontal. The left side of the picture (Fig. 1) is the canyon wall, while on the right a pillar supports one end of the arch. The stream which formed this natural bridge once flowed on the outer side of the pillar, but making a sharp bend, it flowed just in front of the pillar to a point immediately under the near edge of the arch, where it turned and flowed along the foot of the wall toward the front of the picture. The position of this bridge is such that it was very difficult to photograph it so as to show its true relation to the stream. Between the foreground on the right, covered with weeds, and the pillar, one side of which only is shown, is the old channel of the stream. The gorge is about 30 feet deep,

[1] W. B. Scott, *An Introduction to Geology*, pp. 90, 91.

[2] *National Geographical Magazine*, Vol. V, 1893, p. 59.

[3] *American Journal of Science*, 4th ser., Vol. XX, 1905, pp. 119–24; 3 figs.

with almost vertical walls. The rock is a hard, rather blocky, light-blue clay, showing typical bad-land topography and weathering rather rapidly, though not as fast as the softer maroon clays of the Oreodon

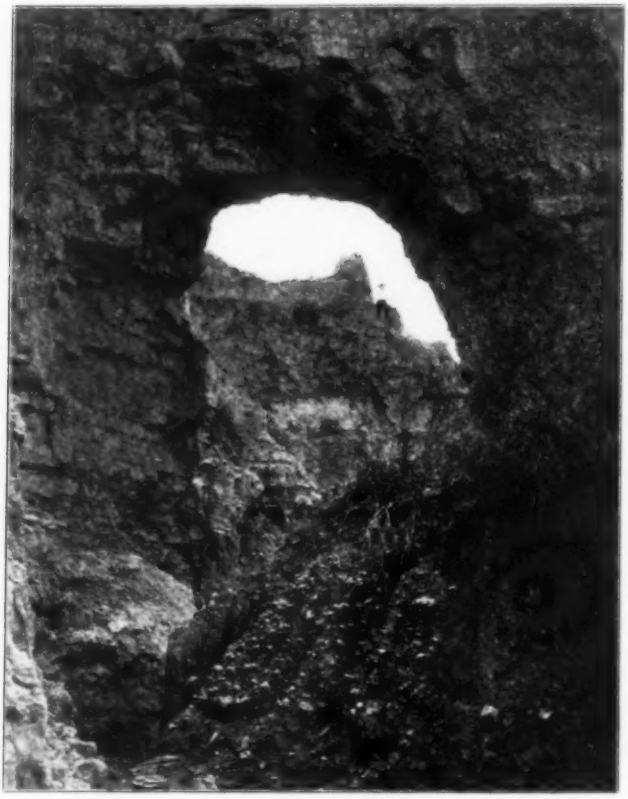

FIG. 1.—A natural bridge south of White River below mouth of Porcupine Creek, South Dakota.

beds. The bridge was formed in the following method: Flowing in the direction indicated by the arrows in Fig. 2, and taking the course of the dotted lines, the stream kept cutting in on the narrow ridge at

A from both sides, until it had eaten its way through, thus straightening its channel but leaving a pillar (*B*) supporting an arch over the stream.

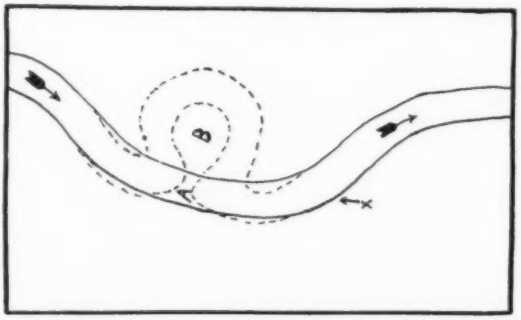

FIG. 2.—A drawing to illustrate the way in which the natural bridge was formed. The view (Fig. 1) was taken from a position indicated by the cross and looking in the direction of the arrow.

STRIATIONS IN GRAVEL BARS OF THE YUKON AND PORCUPINE RIVERS, ALASKA[1]

V. H. BARNETT

The presence of furrows in gravel bars of spreading and meandering streams in Alaska seems not to have been mentioned in the literature on Alaskan geology.

These channels may be seen on the extensive bars of the Yukon and of the Porcupine rivers throughout the Yukon Flats. The bars are remarkably well developed along the Porcupine for about a hundred miles above its union with the Yukon and in low water they are exposed as broad, gravelly, and sandy beaches from one to five miles in extent. These extensive bars give excellent opportunity to observe the striations. An uprooted tree is often seen lodged on a bar with a channel marking its trail (Fig. 1).

Three hypotheses may be offered in explanation of these furrows: first, that they are caused by tree trunks held firmly to the river bottom, either by accumulated débris or ice, and moved forward by the force of the stream; second, that they are caused by blocks of ice beneath a load or ice jam and moved forward in the breakup; or, third, that they are due to trees passing over bars only partly supported by water, the current banking up behind the stump, though having sufficient force to push slowly along, yet not able to remove the marks of the tree.

The third method would seem a simple explanation for the origin of the furrow shown in Fig. 1. Here an uprooted pine tree may be seen at the down-stream side with a straight furrow passing up stream.

It does not seem to the writer that any accumulation of débris that might collect in the roots of a tree would be competent to hold it to the bottom with sufficient force to make the furrows shown in

[1] Published by permission of the Director of the U. S. Geological Survey.

Fig. 2. The force of the water would tend to relieve the roots of any material competent to sink the tree, such as rocks or frozen earth. The only other material at hand to which one might ascribe such a force, is ice.

There is evidence that during the ice breakup of spring, great pressure is exerted on the banks and shallow portions of the stream.[1]

At a number of places last summer the writer observed talus where

FIG. 1

rock fragments were pressed into a pavement. These were seen both along the Yukon and along the Porcupine rivers. Russell[2] in his paper on the surface geology of Alaska speaks of the river ice as producing pavements of pebbles along the banks and of the pebbles being faced and striated on their upper side. These pavements occur between the high-water and low-water lines, and as the water was low

[1] For an account of the "breakup" see F. C. Schrader, "Professional Paper," *U. S. Geological Survey No. 20*, 1904, pp. 15, 16. Also see Stoney, *Naval Exploration in Alaska*, U. S. Naval Institution, Annapolis, Md., 1900, p. 52.

[2] *Bulletin of the Geological Society of America*, Vol. I, 1890, pp. 119, 120.

at the time of the writer's visit, an excellent opportunity was presented to observe them. The pavements are composed of variously sized rock fragments, from a few inches in diameter up to two or three feet, sometimes water-worn, but more often angular, with their upper side smooth and striated parallel to the stream.

There seems no doubt, therefore, that moving ice if equipped with proper means could produce the furrows observed in the gravels.

FIG. 2

Cut banks occur on one side or the other of the rivers throughout the flats, from which spruce trees are certainly tumbling during summer. An uprooted tree held to the river bank by some of its roots would serve as a lodgment for drifting trees and the whole mass would be frozen in the ice as it formed. In the spring, with the heavy pressure of an ice jam, the mass would be dragged along intact, producing such forms as shown in Fig. 2, but ice blocks caught in the jam probably occupy an equally important place in the origin of these lines.

CAUSES OF PERMO-CARBONIFEROUS GLACIATION

The article by David White on "Permo-Carboniferous Climatic Changes in South America" in a recent number of this *Journal* contains a discussion of the causes of that remarkable period of glaciation. One section of the article is headed, "Exaggerated Temperature Effects of Elevation"—a heading that seems to me more appropriate than the author presumably intended it to be; for the temperature effects of elevation, as a cause of the Permian glaciation of South Africa at least, appear to be greatly overrated in the argument there set forth.

It is not to be questioned that elevation of that part of South Africa from which the Permian ice sheet spread across the neighboring lower lands would have been an efficient cause of lower temperature; but at present the chief evidence of elevation is the need of it in the climatic argument; and we are not yet in the position of having so effectually excluded all other causes of glaciation as to warrant the acceptance of the elevation of the area of glacial dispersion on the ground that no other possible cause remains. It is true that the idea of great elevation of the area of dispersion was current among geologists in South Africa when I was there in 1905; but on inquiring more particularly for the evidence in favor of this idea, there appeared to be nothing more than its assumed necessity.

Two reasons are assigned by White as indicative of land elevation: "The enormous accumulations of coarse conglomeratic material in the eastern regions testify to the steep gradient of the drainage systems," and "The presence in nearly all regions of the great unconformity is itself evidence of the vigor of the post-Carboniferous uplift" (p. 631). As I see the case, neither of these reasons can be applied with force to South Africa.

As to the first of these reasons: the Dwyka tillite or glacial conglomerate of South Africa is itself the chief conglomeratic deposit of great series of continental formations in which it is the basal member; the other members are largely sandstones and shales; the Ecca formation, which follows the Dwyka more or less conformably, contains coal seams, which testify to gentle gradients, not to steep gradients in the stream systems. The great total thickness of these continental formations indicates a long-continued progressive depression of their basin, and this is quite as consistent with a long-continued uplift of never-lofty neighboring lands as with a great

elevation of the neighboring lands during the formation of the Dwyka tillite.

As to the second reason: The great unconformity between the Dwyka tillite and the older formations cannot be interpreted in South Africa as meaning a vigorous post-Carboniferous uplift. The underlying deformed formations are all much older than the Dwyka, and were enormously eroded after their deformation before the Dwyka tillite was deposited upon them; hence the time of the pre-Dwyka deformation and uplift which initiated the great erosion resulting in the unconformity must have been pre-Carboniferous, not post-Carboniferous. Indeed, as far as the surface of unconformity has been traced, it everywhere shows forms of small relief; either low, well-subdued mountains, or peneplains; hence a long time must have elapsed between uplift and glaciation. Furthermore, the Waterberg sandstone of the Transvaal, supposed to correspond to the Table-mountain sandstone farther south, and surely older than the Dwyka, because it is unconformably covered by patches of Dwyka tillite, itself rests unconformably upon the eroded surface of the strongly deformed older formations, and here also the surface of unconformity is of small relief; and the Waterberg sandstone is nearly horizontal or gently inclined, thus testifying to the relative absence of vigorous uplifts in the Transvaal for a long period before Dwyka time.

Inasmuch as the Dwyka is associated with continental formations, it may have been deposited in an inclosed continental basin; and if so, it is evident that no safe inference as to the altitude of the pre-Dwyka land surface above sea level can be drawn from the small relief to which the surface had been worn down by pre-Dwyka erosion; for erosion in an interior basin may produce a peneplain at an altitude unrelated to the general baselevel of the oceans. Nevertheless, it is improbable that the interior basin of South Africa stood at a great altitude in Dwyka time; for the southern part of the Dwyka tillite follows conformably after a series of presumably continental shales and sandstones, which in turn rest conformably upon marine Devonian (Bokkeveld) strata: and it is hardly probable that the region which was low in Devonian time could have been raised to a great altitude as an interior basin in Dwyka time without interrupting the conformable sequence of stratified deposits that connect the marine and the glacial formations. True, it is possible to imagine such a case, but the imagined case includes conditions so improbable that they do not form a satisfactory ground on which to build the explanation of the Dwyka glacial climate; far less do they suffice to lead to a demonstrated explanation.

In view of all this, is it not premature to assert that "the elevation of the southern land masses" in Dwyka time is "fully demonstrated"? There certainly were times when parts of the South African land masses were deformed and elevated; but one of these times of elevation was so long before the Dwyka period that the elevated areas had been worn down to small relief when glaciation occurred; and the next occasion of strong deformation and elevation was after all the continental formations, of which the Dwyka is the basal member, had been deposited; and moreover, this elevation occurred well to the south of the area of glacial dispersion. But in Dwyka time, all direct evidence suggests that South Africa was a low-lying continental area. It is of course permissible to postulate an elevated continental area in a region concerning which we have no direct information as to Dwyka topography, north of the northernmost Dwyka tillite patches in the Transvaal; and this postulated highland may be regarded provisionally as the source of the Dwyka ice sheet; but postulating an elevation and demonstrating it are very different processes.

White says also that "the occurrence of glacial phenomena within the tropics was presumably due in part to an extension of the southern cold with the favoring assistance of ocean currents and perpetual atmospheric 'lows,' resulting in part from continental relations and topography" (p. 631). Here again, it is perfectly legitimate to postulate favoring ocean currents and perpetual atmospheric "lows," if one wishes to do so, and then to deduce the consequences of the postulates; but the value of the deductions will necessarily depend upon the validity of the postulates themselves; hence they must be examined. Ancient currents in the ocean and areas of low pressure in the atmosphere should not, in the present state of scientific inquiry, be arbitrarily assigned to this or that part of the world. The existing currents of the ocean and areas of low pressure in the atmosphere are so systematically arranged that one may fairly object to any assumed ancient distribution of these phenomena that is inconsistent with the controls by which they are determined today. For example, a continental area of low pressure in latitude 25° can occur only in the warm season, when the high temperature on the land may suffice to reverse the tendency to high pressure perpetually induced in that latitude by the processes of planetary (atmospheric) circulation; and the relatively high temperature by which a low-pressure area is formed in such a region is evidently unfavorable to the occurrence of snowy precipitation. In the cold season of the same region, when the temperature is more favorable to snowfall than at other times, the atmospheric pressure will be high, but precipitation in the area of high pressure will be small. Hence little aid

can be given to Dwyka glaciation by areas of low pressure. It may be the same with ocean currents. Until a reasonable cause can be given for the occurrence of favoring ocean currents, their part in aiding the formation of the Dwyka ice sheet is only a gratuitous postulate. However satisfactory an explanation of a problem is, reached from such a postulate, it is not safe to regard the explanation as fully demonstrated until the postulate is independently established. The desirable thing in such a problem as this is the publication of diagrams, on which the distribution of lands should be indicated as described by White—"an Antarctic continent, of which Australia, South Africa, and a part of South America were possibly but lobes" (p. 630)—with a reasonable and warrantable distribution of ocean currents and areas of low atmospheric pressure in proper relation to the postulated lands and oceans. It would then be possible for a reader to judge how much favoring assistance might be expected from these contributive causes.

The Permian glacial climate is one of the most remarkable problems disclosed by geology. The addition of a South American glaciated area to the others in Australia, India, and South Africa goes far, as White points out, toward excluding any recourse to tempting explanations based on the displacement of the earth's axis. The present limitation of precipitation in at least the South African glaciated area chiefly to the warmer season, while the colder season is prevailingly clear and dry, is a difficulty that must not be overlooked. The full explanation of the problem does not involve only a moderate reduction of temperature; it involves either so strong a reduction of temperature that snowy precipitation may prevail in the warmer season, or a more moderate reduction of temperature with a change of the season of precipitation from the warmer to the cooler part of the year. Under the present understanding of atmospheric circulation, the first of these alternatives is less puzzling than the second.

W. M. DAVIS

HARVARD UNIVERSITY
November 24, 1907

Reviews

The Okanagan Composite Batholith of the Cascade Mountain System. By Reginald A. Daly. (Bulletin of the Geological Society of America, Vol. XVII, pp. 329–76, 1906.)

This batholith is on the international boundary between British Columbia and the state of Washington. Its east-west dimension is about sixty miles; the north and south limits are not known. The batholith is composite, the individual intrusions having been made from late Paleozoic to late Tertiary time. There is considerable variation petrographically in these intrusions, the later ones being as a whole progressively more acid, but the series was broken near the close of the Laramie by the intrusion of some alkaline syenites and malignite. The small Paleozoic bodies are a complex, variable, highly metamorphosed series of gabbros, peridotites and dunite. The Jurassic batholiths are of granodiorite, and the Tertiary batholiths are of biotite-hornblende-granite and biotite-granite. There are a few dikes of olivine basalt, thought to be of Pleistocene age.

It is evident from Daly's descriptions that these rocks are in general accord with the rest of the Pacific Coast petrographic province in their moderately high ratio of soda to potash.

In Lower Cretaceous time the Jurassic granodiorites had been exposed by erosion, and over 30,000 feet of arkose sandstones, grits, and conglomerates were deposited on them. This was followed by deformation, which resulted in the production of faults and folds in the Cretaceous strata, with dips averaging over 45°. Probably at the same time the granodiorites were sheared and crushed into banded gneisses and gneissic granites.

The method of batholitic intrusion by replacement is discussed, and an ideal skeleton history of a batholite is given.

C. W. W.

Crescentic Gouges on Glaciated Surfaces. By G. K. Gilbert. (Bulletin of the Geological Society of America, Vol. XVII, pp. 303–16; Pls. 37–39. 1906.)

The chatter-mark and crescentic crack are described. The former is thought to be due to the slow, rhythmic striking of bowlders embedded in the basal ice. Fracture results, if the surface of the rock is under tension.

Crescentic cracks which are vertical and, like chatter-marks, are concave forward, may be explained as the result of the difference in stress parallel to the rock-face, arising from differential friction.

Crescentic gouges are convex forward (downstream). Those here described measure from a few inches to over six feet across. The gouges generally occur in sets, the members of a set being usually of nearly equal size. They occur on both bottoms and walls of glacial troughs. Crescentic gouges consist of two elements: a gently sloping, incomplete, conoid fracture, on the upstream side; and a subsequent, vertical, crescentic fracture, that forms the downstream side of the gouge. The "conoid" fracture is due to shear from an inclined pressure arising from the downward and forward pressures of the ice, as modified by differential friction. This inclined pressure is thought to have been applied by bowlders acting through a thin cushion of débris or of débris-loaded ice, at places where the ice rose over obstructions. The thin wedge formed by this fracture was broken across vertically, and the crescentic wall produced. This second break is due to stress from the upturning of the edge of the wedge when the formation of the first crack relieved it of compression, and the resistance of the ice pressure against this upturning.

The author regards the gouges as the result of "a mechanical rhythm of some sort," and suggests that the constant pressure of the ice may induce a group of mechanical rhythms to accumulate stress and strain within the rock, until the breaking-point is reached and a conoid fracture produced.

C. W. W.

Geological Reconnaissance of the Coast of the Olympic Peninsula, Washington. By RALPH ARNOLD. (Bulletin of the Geological Society of America, Vol. XVII, pp. 451–68; Pls. 55–58.)

This paper gives the preliminary results of the first measurement and study of any comprehensive Tertiary section in the Pacific Northwest.

The topography of the Peninsula is not very well known. Its dominant feature is the Olympic Mountains, a rugged alpine group rising to a maximum elevation of 8,200 feet, and having a local relief of about 7,000 feet. There are no railroads, wagon roads, or trails in the higher mountains, and considerable areas are almost impassable even to a man afoot.

Surrounding the higher mountains, especially on the northwest, west, and south sides is a maturely dissected plain, sloping seaward from elevations of 4,500 to 5,000 feet. The streams crossing this plain, in fact all the streams of the Peninsula, flow nearly straight outward from the central

area of high mountains. This radial drainage is thought to be consequent to some domed surface, probably a peneplain.

The formations involved in the geology of the coastal region of the Olympic Peninsula include serpentine, old diabase or greenstone, metamorphosed sandstone, and quartzite, probably of Jurassic age; 6,000+ feet of gray sandstone with minor quantities of carbonaceous shales, supposed to represent the lower part of the *Puget Group* and of Cretaceous age; 1,200+ feet of basalt tuffs of Eocene age; 15,000 feet of Oligocene-Miocene conglomerate, sandstone and shale; 2,260 feet of Pliocene conglomerate, sandstone, and shale; and at least 300 feet of Pleistocene till, clay, and gravel.

Fossils are abundant in the Tertiary formations. One fauna is described from the Eocene, five from the Oligocene-Miocene, and one from the Pliocene. The peculiar upper Miocene fauna of the Looke beds, which is well developed on Vancouver Island, only 15 miles northward, is conspicuous by its absence.

C. W. W.

Contribution to the Geology and Paleontology of Vermont. By HENRY M. SEELY. From the *Fifth Report Vermont State Geologist*, pp. 1–34, Plates XXXIV–XLV. Montpelier, Vt., 1906.

The greater part of this paper is taken up with description of new species of the so-called genus, Cryptozoön. None of the characters assigned to these three new species, *C. steeli*, *C. saxiroseum*, and *C. wingi* differ from structures that may be occasionally observed in undoubted concretions. The reviewer can find no reason for regarding such structures as organic, except to the extent that bacteria or similar organisms may have contributed to the precipitation of the calcite or silica composing them. In fact the only structure in Hall's description of the type species[1] that may be organic is certain doubtful canals, of which he writes: "The substance between the concentric lines, in well-preserved specimens, is traversed by numerous minute irregular canaliculi which branch and anastomose without regularity." The exact nature of these is not clear, but probably they are similar to the "pilae" figured by Seely (Plate XXXVII, Fig. 3) which cannot be distinguished from irregular inorganic segregations common in many concretions, cherts, and limestones.

A startling feature of the paper is the description (p. 12, Plate XXXVII, Figs. 5, 6) of a specialized ovarium with ova in "Cryptozoön saxiroseum." That such a structure, so well developed, should exist in so primitive an

[1] James Hall, *Thirty-Sixth Annual Report N. Y. Mus. of Natural History*, transmitted to the legislature, January 12, 1883. (*Cryptozoön proliferum.*)

organism as "Cryptozoön" would be, is not probable. Perhaps the structure is the shell of some specialized organism included in the concretion. Until someone can find organic structures in "Cryptozoön" the description of new species is an unnecessary burden to science.

C. W. W.

On the Radioactive Matter in the Earth and the Atmosphere. By A. S. Eve. Separate from the *Philosophical Magazine*, September, 1906, pp. 189–200.

For geologists, the most important feature of this paper is the determination of the radioactive matter in the earth's crust. "About 1.8×10^{-11} grams of radium bromide is the estimated equivalent of the active matter per c.c. present in the earth's crust sufficient to account for the penetrating radiation." This is four times the average amount found by Strutt by direct observation on rock specimens.

C. W. W.

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